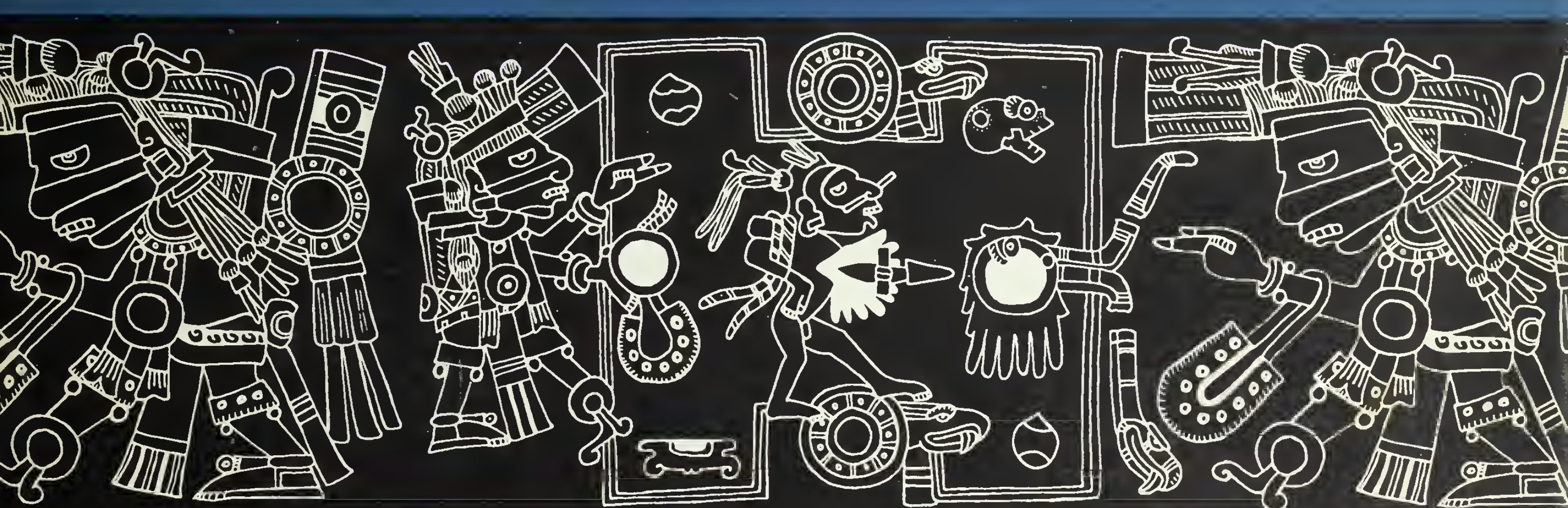
THE PREHISTORY OF THE TEHUACAN VALLEY

DOUGLAS S. BYERS, General Editor

VOLUME ONE

Environment and Subsistence



R. S. MacNeish, Douglas S. Byers, and Others

Insatiable curiosity about the origins of New World civilization and agriculture—in the New World this means Indian corn—led archaeologist R. S. MacNeish to undertake a hunt that eventually led him to a cave in the arid Tehuacan Valley of east central Mexico. There, in 1960, he found what he believed to be his goal. The Tehuacan Archaeological-Botanical Project, sponsored by the R. S. Peabody Foundation for Archaeology, Phillips Academy, Andover, Massachusetts, was organized by MacNeish in order to take full advantage of his initial discovery.

Under his leadership, field parties spent four seasons searching through rubbish of long-dead towns and millennia-old litter of hunting parties for traces of early corn and its wild ancestors, and for first evidence of civilization. They succeeded in establishing an unbroken record spanning 9,000 years and covering most aspects of man's life. This is the longest continuous record of man's economic activities yet found anywhere.

A team of scholars, many trained in fields other than archaeology, have interpreted for us the significance of this record. Midway in its course plant breeders set about improving wild food plants, with the result that corn, avocados, and other plants of importance today eventually took on their modern form.

The greatly increased yield of the improved plants furnished reserves of food to support artists, astronomers, priests, engineers, city planners, and rulers. Although corn was long known to be the foundation of New World civilizations, its origin remained a mystery until the Tehuacan Archaeological-Botanical Project uncovered tiny cobs that almost duplicate the hypothetical wild ancestor of corn bred by Paul C. Mangelsdorf.

Volume I, *Environment and Subsistence*, is concerned principally with geography, climate, and the natural resources exploited

(Continued on back flap)

5 vols

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Environment and Subsistence

Edited by Douglas S. Byers

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EDITOR'S PREFACE

The Prehistory of the Tehuacan Valley will make known the findings of The Tehuacan Archaeological-Botanical Project, which, during four field seasons, 1961–1964, sought to discover the beginnings of agriculture in the New World and the concomitant rise of autocthonous civilization. This project, supported by the National Science Foundation and the Rockefeller Foundation, was the brain child of R. S. MacNeish, Research Associate, R. S. Peabody Foundation, who envisaged it as an interdisciplinary project. As such, it was the first of its kind to be undertaken in Middle America.

Assembled in a team to collect data or analyze material gathered in the course of archaeological excavations were people trained in botany, zoology, geology, and anthropology. Any lack of either the "inter-" or the "discipline" in the resulting papers may well stem from the pioneering nature of this study. At this stage, it is easy to see how the project might have been carried out to better advantage for all contributing sciences. Although preliminary reports of some of the findings have appeared elsewhere, a number of "first" papers for the region will appear in this series.

This, the first of the six volumes that present the findings, is concerned primarily with fields other than archaeology, with the Tehuacan Valley and its immediate surroundings, with its natural history and natural resources, with its people, and with the exploitive activities of a people faced with the necessity of wringing the greatest possible advantage from what appear to have been the progressively deteriorating resources of an increasingly more hostile and discouraging environment. In this volume are included data bearing on the domestication of native American plants and their subsequent improvement. Findings regarding the domestication of maize should answer many questions concerning the origin of this important crop plant, but leave many more still to be answered. That other economic plants were exploited at an even earlier date will come as a surprise to many.

Lack of space and problems of time have made it impossible to include in this volume extensive information about the development of irrigation that has been gathered by R. B. Woodbury and his colleagues. In spite of its obvious connection with agricultural activities, this material had to be relegated to another volume.

Volume II is concerned with the nonceramic artifacts of the ancient inhabitants of the Tehuacan Valley, and with the identification and seriation of types of artifacts to derive a chronology for the valley. It is also concerned with the distribution of such types and with the possibilities of such distribution in time and space as a means of reconstructing cultural units and their relationships, whether locally or on a wider scale.

Volume III will be concerned with ceramic artifacts. The sherds, vessels, and figurines unearthed in the excavations will be described, discussed, and used in the reconstruction of the cultural and mercantile history of the valley and in the placement of the burgeoning cities and principalities with respect to contemporary developments in Mexico beyond the rim of the Tehuacan Valley.

Volume IV will be concerned with chronology, both relative and absolute. Stratigraphic relationships and succeeding types of artifacts will provide the key to relative chronology, but radiocarbon dating holds the key to absolute dating. By combining the two—absolute chronology and relative chronology—an estimate of the rate of growth of the culture, progressively increasing in richness and complexity, can be derived.

Volume V will comprise detailed reports of the archaeological survey and of the several excavations, with sections to show stratigraphic relationships in the ground. It will also attempt to reconstruct the way of life represented by each occupational unit.

Volume VI, the concluding volume, is intended to contain a summation of what has been presented in the other volumes and to draw conclusions regarding the processes which transform a simple, gathering society into a complex, sophisticated, and urban civilization based on differences of class and caste.

We have attempted to instill some unity into these

volumes. That these attempts have not been completely successful will be apparent to the casual reader. It is difficult to process so many manuscripts from so many authors in such a way as to eliminate all differences in style. It is obviously impossible to force agreement on all, even though some individual contributions depart radically from findings of other contributors. To attempt to do so would be to smother with a protective editorial blue-gray what may eventually prove to be strokes of genius and insight.

The National Science Foundation has supported the preparation of these manuscripts, even though it has seemed a never-ending job. To the successive program directors for Anthropology, Allan H. Smith and Richard W. Lieban, and through them, to the National Science Foundation, we express our gratitude for their patience and encouragement.

We gratefully acknowledge the very considerable contributions to this volume made by Frederick Johnson. He organized a conference among authors out of which this volume took shape. He hammered out, and in large part reshaped, manuscript for several chapters. The success of illustrations for other chapters is entirely attributable to his interest and painstaking care.

To Nancy H. Flannery, of the Tehuacan Archaeological-Botanical Project, we are indebted for various pieces of art work in more than one volume. The skillful and capable hands of Ashley Baker, of the Robert S. Peabody Foundation for Archaeology, have turned to the illustration of the chapter on the Borgia Codex as well as to other art work and the making of photographic prints. She has been of inestimable help in preparing the many complicated tables in Volume I.

It would have been impossible to carry the work to completion without the discerning and sympathetic efforts of Chase J. Duffy, who has carried the major editorial load.

DOUGLAS S. BYERS
Director, Robert S. Peabody Foundation
Andover, Massachusetts
August 1966

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ENVIRONMENT AND SUBSISTENCE

Introduction

by Richard S. MacNeish

I FIND IT difficult to begin the Tehuacan reports except on a personal note, because the seasons spent in the field at Tehuacan have been among the most exciting and satisfying of my life. Since childhood I have been interested in Mayan and Mexican archaeology and in the processes by which these civilizations came into being. Later, of course, I learned that the origin of civilization is closely connected with the development of agriculture, and that in the New World this meant corn. I spent many years before I undertook this study of the rise of civilization in Tehuacan in tracking down leads on the origins of corn agriculture.

For me the Tehuacan project really began in 1945–46, when at the urging of Dr. Fay Cooper Cole and under the auspices of the Department of Anthropology of the University of Chicago, I undertook an archaeological reconnaissance of coastal Tamaulipas in northeastern Mexico to seek prehistoric cultural connections between Mesoamerica and the southeastern United States. In the course of this project we uncovered evidence of early man and two ancient cultural complexes characterized by food-gathering and the first steps toward agriculture. The season was also important to me because I gained valued experience in surveying and finding preceramic sites in Mesoamerica. I had learned at first-hand that caves in the drier regions of Mexico did indeed contain stratified preceramic remains, and that among these were remains of plants.

This first endeavor added little to the search for early corn and the origin of its domestication—but neither had previous archaeological research in Mesoamerica. Archaeological work before 1945 in South America and Mexico had led to a belief that corn agriculture had not been practiced there much before 1000 B.C., nor was the cultivation of corn thought to be older than the Christian era in the southwestern United States. Contemporary botanical studies concerned with the origin of corn advanced three theories: (1) that corn had evolved from the wild grass, *teosinte*, in Mesoamerica; (2) that corn had evolved from a grass in South America; and (3) even that corn had been first domesticated from a local grass in southeast Asia. We were a long way from having any answers to the corn problem, and our guesses were not even very close.

In 1948 and 1949 the situation changed for the better. Tiny primitive corn cobs were uncovered in the summer of 1948 at Bat Cave, New Mexico. Later, charcoal found with them placed their age between 3000 and 5000 years. Almost as important as their antiquity was the submission of the cobs by their finder, Herbert Dick, to Paul C. Mangelsdorf, Fisher Professor of Natural History at Harvard University, for study and analysis. At almost the same time, digging in La Perra Cave during the second Tamaulipas expedition in early 1949, I uncovered other remains of primitive corn. Some of this, dated by radiocarbon laboratories to about 2500 B.C., also found its way to Mangelsdorf's laboratory. He discovered that the early corn from La Perra Cave exhibited certain similarities to Nal-tel, one of the primitive modern races of maize previously defined by Wellhausen, Roberts, Hernandez, and Mangelsdorf (1952). Mangelsdorf identified the earliest La Perra corn as pre-Nal-tel (Mangelsdorf, Galinat, and MacNeish 1956).

The sum of this research indicated that corn was probably first domesticated in Middle America rather than in South America or Asia, and quite possibly before 3000 B.C. Furthermore, these investigations indicated clearly that the origin of domesticated maize could best be discovered by cooperative research between botanists and archaeologists.

In the next stage of our investigations—from 1951

to 1955—Mangelsdorf and I made a concerted effort to seek the elusive first domesticated corn. As part of this effort I went to southwestern Tamaulipas. My findings there proved definitely that corn was domesticated, not in, but to the south of that region. Other information began to come in from several sources.

Fig. 1. The search for early maize in the southwestern United States and Mesoamerica.

Robert H. Lister, working in Chihuahua and Sonora, uncovered remains of corn which demonstrated that corn was originally domesticated to the south of those states. Meanwhile research by P. B. Sears and K. H. Clisby (1955) in the Valley of Mexico led us to think that corn was domesticated still farther south, even though pollen identified as that of maize, and probably wild maize, was found in a drill core in levels assigned to a much more ancient era than the pollen judged to be from domesticated corn and found in more recent levels (Barghoorn *et al.* 1954).

Because of the findings in northern Mexico we moved operations considerably farther south. In 1958 I looked for dry caves in Honduras and Guatemala. Although I found remains that were possibly preceramic, they included no corn. The following year, Frederick A. Peterson, who had been with the New World Archaeological Foundation, and I started excavations in Santa Marta Cave in southern Chiapas. Studies of pollen secured there indicated that the corn pollen was not sufficiently old to justify consideration of that region as corn's homeland. It seemed that Chiapas was too far south, just as Mexico City, Tamaulipas, and northwest Mexico were too far north.

As a result of our archaeological efforts up to 1959, we believed that corn probably was domesticated before 3000 B.C., very likely in an area south of the Valley of Mexico but north of Chiapas. Mangelsdorf's studies pointed to the probability that the ancestor of corn was a highland grass not unlike the pod popcorn found in Bat Cave and southwest Tamaulipas. Previous finds had revealed that plant remains were to be found in dry caves in dry regions. We also knew that caves or rock shelters usually are to be found in deeply dissected country. A study of rainfall, climate, topography, and geological data revealed only three likely regions that could meet these requirements. One was in southern Oaxaca, another was the Rio Balsas or Mescala region of Guerrero, and the third was the Tehuacan Valley of southeastern Puebla and northeastern Oaxaca.

Although I briefly visited Oaxaca and the Tehuacan Valley at the end of the 1959 season, I did little cave hunting. Perhaps the most profitable part of this initial visit was my meeting Sr. Ricardo Gutiérrez, at that time assistant manager of the Hotel Peñafiel in Tehuacan, who enthusiastically helped me pursue my "corn hunt" in many ways. A brief search around Mitla, Oaxaca, after Christmas in 1959 revealed numerous caves, probably with preceramic remains, but none seemed dry enough nor the refuse deposits deep enough to contain really old corn, so I returned to Tehuacan. There, in January 1960, through Sr. Gutiérrez, I met Luis Vásquez, Director of the Museo de la Revolución in Puebla, who generously gave his help in furthering my project. Armed with an official federal permit from Arturo Romano of the Instituto Nacional de Antropología e Historia, a series of letters to local authorities, and equipped with borrowed gear, I began explorations in the Tehuacan area.

In the company of a bored army lieutenant from the local base who was under orders to guard me, I made my first foray along the highway between Chazumba and Huajaupan de Leon, Oaxaca, visiting sixteen caves. All were in volcanic deposits too porous for the preser-

vation of vegetal materials. Four other caves south of Ajalpan were equally unproductive. A second trip, this time under the protection of a very perplexed sergeant, netted four caves near Zapotitlan, Puebla, and one cave just past Tequixtepec, Oaxaca. The latter and one of the Zapotitlan caves gave indication of containing stratified fill which might conceal preserved organic remains, but both shelters were very small. Other caves, visited in the company of a sleepy army private, included five near the town of El Riego, just north of Tehuacan, three northeast of a town along the highway to Veracruz, and three only one kilometer south of the town of Tehuacan. All had possibilities, but the prospects of finding remains of early corn in any of them did not appear to be great.

After looking at three dozen sites without much success, I turned to a series of forms that local school teachers had filled out for Luis Vásquez. Three of these forms mentioned caves in the *municipio* of Tehuacan; one respondent spoke of a cave near Altepeji, and another of a cave east of Ajalpan. I visited these, at last by myself, but they revealed little of interest. The third cave, said to be located in the hill called Agujereado south of the town of Coxcatlan, was described by Señorita Berta Martínez of that town. Eventually, after a number of inquiries, I found Señorita Martínez. She kindly arranged for her brother Hector and a guide, Pablo Bolanos, to take me to this cave, some ten kilometers south of Coxcatlan. After a long, hot walk along the edge of the mountains, through thick stands of cactus and mesquite, we arrived at the rock shelter. Even from a distance it looked promising. The artifacts and refuse on the surface, the size of the shelter, and the quantity of vegetal material that lay beneath the goat dung covering the floor showed that this was a site to be tested.

From January 21 to January 27 the three of us, Pablo, Hector, and I, tested this cave. Behind a large rock roughly in the center of the shelter we dug a two-meter square to a depth of about two meters, using trowels. We took out everything, including the loose dirt, by bucket loads and put it through a mesh screen to be sure that we missed nothing. Slowly we peeled off the successive strata. The uppermost layer yielded Postclassic remains; the stratum underlying it contained Classic and a few Formative sherds; then there was a sterile layer. Underneath that was a thick layer which was obviously preceramic. On January 27 after lunch, Pablo, working well down in the preceramic stratum, recovered a tiny corn cob no more than an inch long. Only half believing, I took his place in the bottom of the pit. After a short period of troweling and cleaning away dirt with a paint brush, I uncovered two more tiny cobs. We held in our hands possible ancestors to modern domesticated corn.

This impression was confirmed a month or two later by Mangelsdorf when he examined the cobs at Harvard University. Still later the cobs were dated to 3610 B.C. ± 250 years (M–1089). This radiocarbon determination on associated charcoal was made at the University of Michigan Laboratory through the kindness of James B. Griffin, Director of the university's Museum of Anthropology. These were the oldest corn cobs that had ever been found!

After January 27 we did little further digging in what came to be known as Coxcatlan Cave. I made a preliminary reconnaissance of the valley and also began to analyze the material we had uncovered. The last event of this first season at Tehuacan took place on February 8 when José Luis Lorenzo, then Director of the Escuela Nacional de Antropología, paid us a visit. Lorenzo realized the importance of our finds and came to Tehuacan to offer his assistance, an assistance he continued to give generously for the next four years.

By the spring of 1960, we thought we knew approximately where corn had been first domesticated, and we had a few examples of this earliest corn as proof (see map). Furthermore, we had found at least one stratified site. Better yet, Tehuacan occupied a strategic position in almost the exact center of Mesoamerica. The possibility that in this region we might find evidence of the development of agriculture and the concomitant rise of civilization was fairly great. Therefore, with considerable help and advice from Paul Mangelsdorf, I made an initial plan for the Tehuacan project. Feeling fairly confident that we would eventually be able to carry out the plan, I also wrote Fred Peterson, who had been of great help at Santa Marta Cave, C. Earle Smith, and others to see whether they would be available for the proposed research.

Because of its demonstrated interest in interdisciplinary projects and the flexibility of its organization, we felt that the Robert S. Peabody Foundation for Archaeology was well qualified to administer a collaborative project such as we envisaged. Accordingly I discussed our plan with Douglas S. Byers and Frederick Johnson, Director and Curator, respectively, of that institution. Expressing interest, they helped work out a program of research to be carried on under the auspices of the Peabody Foundation. This program was embodied in a proposal submitted to the National Science Foundation in September 1960. Briefly, our main purpose was to investigate the development of agriculture and the concomitant rise of civilization

in Mesoamerica. The area of research was to be the Tehuacan Valley in the Mexican states of Puebla and Oaxaca. Our approach was to be interdisciplinary, utilizing the skills of all appropriate scientific fields. The immediate objectives were as follows: (1) To find and excavate a series of stratified sites with preserved remains of plants and animals used as food by the inhabitants; (2) to establish a relative and an absolute chronology for the Tehuacan Valley; (3) to reconstruct, as completely as possible, changes in aboriginal patterns of subsistence and to bring this information to bear on the problem of the origin and spread of agriculture in the New World; (4) to reconstruct the cultural pattern of each stage of the complete Tehuacan sequence; and (5) to compare the Tehuacan sequence with similar sequences found in other parts of the world in the hope of learning how civilization develops and why it develops.

This program was to be carried out by a relatively small field crew of archaeologists who would be working in close co-operation with botanists, paleontologists, zoologists, ethnographers, malacologists, and others whom we planned to bring to Tehuacan. Among the botanists were to be persons whose special skills and knowledge centered on studies of corn, squashes, beans, and the analysis of coprolites.

Our proposed schedule allowed three seasons to complete the task. During the first season, 1960–61, we intended to make an archaeological survey and a botanical reconnaissance and to carry out a few limited excavations; during the second season, 1961–62, we proposed to complete the survey and undertake our main excavations, while the first group of specialists would begin their studies in Tehuacan; during the final season, 1962–63, the specialists were to complete their studies, the archaeological analysis was to be completed, and the final reports written.

Now that I look back on this original schedule I am surprised to find how closely we followed its spirit, even though we did not carry through each detail exactly. Obviously, field conditions changed, unforeseen circumstances arose, personnel came and went, but perhaps the factor that most changed our specific plans was that we just simply did better than we had expected to in the beginning. We found more sites, more stratigraphy, more artifacts, more preserved organic material than any of us (Byers, Johnson, and I) ever guessed would be possible. Oh that I can always be wrong in my estimates for reasons such as these!

Inherent in the original Tehuacan project was the intention of incorporating data from as many different sources as possible. We felt that the inclusion of such data would not only give us a fuller history of the region, but that the co-ordination of information from a number of fields might be mutually stimulating. Ideally, our specialized studies were to have begun after all the relevant data had been excavated (and dated at least relatively) and the particular problems of each discipline had been defined. The scientist concerned with a special study was then to come to Tehuacan not only to work with his own particular set of data, but to see the region and the excavations as background for interpreting his data. Finally, as the various reports and analyses were completed, we hoped there would be an exchange and a co-ordination of each set of information which would solve a wide variety of problems.

Chronologically, our first specialist was Miss Monika Bopp, who came to Tehuacan in the spring of 1961 to collect pollen from the profiles of our excavations. However, before she could analyze her samples she married and left Mexico. In the spring of 1963, James Schoenwetter came to Tehuacan also to collect pollen. Eventually the pollen samples were sent to Elso S. Barghoorn and Henry Irwin of Harvard University. The purposes of the pollen studies were to determine the agricultural changes, give us clues as to chronology of the strata of the various sites, and to determine the changes of vegetation through time. Because of poor pollen preservation in our earlier levels, these worthy objectives were not attained.

C. Earle Smith, now with the United States Department of Agriculture, Crops Research Division, came to Tehuacan in the summer of 1961 to make a botanical survey of the valley and into the surrounding mountains. He continued the survey in August of 1962, and in 1963 he identified the vegetal remains from the archaeological sites. His subsequent analysis of these materials gave us pertinent information on the flora of the valley as well as much information about the ancient subsistence patterns.

Closely allied to the study of the ancient subsistence were the analysis of the archaeological cucurbits, undertaken in the spring of 1962 by Hugh C. Cutler, Executive Director of the Missouri Botanical Gardens, and Thomas W. Whitaker, Senior Research Geneticist of the United States Department of Agriculture; the study of beans, made in the fall of 1962 by Lawrence Kaplan, now with the University of Massachusetts in Boston; and the studies of corn undertaken by Paul C. Mangelsdorf and Walton O. Galinat of Harvard University. In order to obtain more precise information about diet Eric O. Callen of Macdonald College of McGill University undertook a study of the pre-

historic feces preserved in the dry rock shelters. His study, initiated in 1962 but lasting until 1964, was carried out in painstaking and minute detail.

Supplementing these studies on subsistence and environment were the zoological researches. Kent V. Flannery, now with the Smithsonian Office of Anthropology, arrived in the summer of 1962 to make a faunal survey of the Tehuacan Valley. In 1963 he analyzed the numerous animal remains that had been uncovered in excavation. This information added not only to our knowledge of the ancient subsistence but also gave us hints of changing environments. The correlation of all this information, both zoological and botanical, gave us a rather full picture of the diet and also indications of the actual seasons of the cave occupations.

Furthermore, data derived from the botanical and zoological studies furnished us with hints about chronology in the Tehuacan region. However, the most significant endeavors in this line were in the capable hands of Frederick Johnson of the R. S. Peabody Foundation. Not only did he teach the archaeologists in 1962 and 1963 how to collect carbon carefully, but he collected the majority of the carbon specimens himself, organized the information about them, and then selected the specimens which were to be sent to Isotopes Incorporated for radiocarbon determinations. Finally, it became his lot to interpret the material dated.

Beside these studies which are easier to classify together, other specialized information came from a variety of sources. Geological studies of the Tehuacan Valley were made by Jean Brunet of the Centre Scientifique et Technique Français au Mexique. Geographical studies of the region were made by Douglas S. Byers of the R. S. Peabody Foundation. Prehistoric and modern irrigation systems were investigated by Richard B. Woodbury, Acting Head of the Smithsonian Office of Anthropology; James E. Neeley; and Aubrey W. Williams, Jr., of the University of Maryland. James E. Anderson, now of the University of Toronto, undertook a study of the morphologic features of the human skeletal remains taken from the excavations. Most of these studies took place in 1964 and continued after the field project closed. At various times information was collected concerning the ethnohistory and ethnography of the Tehuacan Valley by Carmen Cook, Aubrey W. Williams, and Robert Chadwick.

All in all, these specialized studies yielded information from a wide variety of sources. I have described them under different subdivisions and in terms of a number of different problems—and yet this aspect of the project was a co-ordinated set of research and functioned as a unit with the purpose of understanding the Tehuacan region's ancient history. Part of the unifying process came from the participants' reading one anothers' reports and articles, some of it came from correspondence, much of it came from endless arguments and discussions, both formal and informal, by the various expedition members. Our researches in Tehuacan taught me how artificial are the barriers between the different disciplines and how stimulating it can be to break through them.

The first season of the Tehuacan Archaeological-Botanical Project began in December 1960 when Frederick A. Peterson, C. Earle Smith, Melvin L. Fowler, and I met in Chicago to plan our initial program. We arranged for the purchase of a jeep, which Peterson was to drive to Mexico, where I would meet him early in January. Smith found that his schedule would permit him to come to Tehuacan the following summer to initiate his botanical survey. Fowler, now at the University of Wisconsin at Milwaukee, would join us in Tehuacan in March.

Early in January 1961 I arrived in Mexico City, where Peterson and I spent two weeks bargaining for and buying field equipment. José Luis Lorenzo, as Director of the Departamento de Prehistoria, Instituto Nacional de Antropología e Historia, issued us an official federal archaeological permit. This was one of many ways in which the Tehuacan project was indebted to INAH. This institution, under the able direction of Dr. Eusabio Dávalos Hurtado, made available to us facilities, equipment, and knowledge without which our task would have been immeasurably more difficult. We wish here to express our appreciation to Dr. Dávalos for his many kindnesses.

We proceeded to Tehuacan, where we finally established our headquarters in the downtown area, in a rented house large enough to accommodate most of the scientific personnel as well as the household staff. At first we used the house only as sleeping quarters and office and took our meals elsewhere. Fortunately this period did not last long. Mrs. Peterson—Angelita to all of us—came in March to assume responsibility for the house. She brought with her Guadelupe and Francisco Molina. Lupe became our cook and Francisco became indispensible to the operation in many ways.

Although I had undertaken some archaeological survey alone in 1960 and my testing of Coxcatlan Cave had yielded significant results, our first task in January of 1961 was further reconnaissance. Initially, Peterson and I sought by survey to delimit the region in which we were to work. The area had to be dry if we were

to find remains of food plants from which to establish a sequence of developing agriculture. There had to be, as well, some measure of cultural coherence if we were to trace the rise of a civilization. We therefore commenced by working round and round the Tehuacan Valley, gradually eliminating surrounding areas where the cultural materials or artifacts characteristic of the valley were no longer dominant or areas which lacked semidesert features. During January and February of 1961, having defined the region in terms of these factors, we started an intensive search for sites. At first, Peterson and I carried on the hunt alone. We soon found that Angel García Cook, a student from the Escuela Nacional de Antropología who was sent to us by José Luis Lorenzo, had learned the technique of making an archaeological reconnaissance, so I left the two to carry on without me.

In the meantime, I made preparations for the excavation of Coxcatlan Cave, for Fowler was to arrive toward the end of March. Before we could undertake a large-scale excavation there, we had to cut a road from the highway to the cave through the spiny scrub and cactus. While Peterson and the crew of workmen prepared the road, I began staking out the area to be excavated and started two small cross trenches into the cave. Fowler joined us as planned and eventually took over the excavation. We started with a modest crew of three men, which we gradually increased to about twenty by the end of April, as the excavation became increasingly productive and the workers increasingly well trained. Angel García moved to the cave as student supervisor and assistant to Fowler, where he learned excavation techniques so well that he was soon well qualified to run a dig by himself.

As specimens came in from this excavation, it became clear that we needed a laboratory assistant, and again we appealed to our friend Lorenzo, who sent Miss Antoinette Nelken of the Escuela Nacional de Antropología to fill the post.

I had by this time started excavations in the small cave called El Riego, just north of Tehuacan. There I dug with García as my assistant for about a week until I realized that he knew my methods as well as or even better than I and could run the dig without me. By the end of May, García was running the second excavation in El Riego Cave while Fowler was about to finish the first season in Coxcatlan Cave. All this time Peterson, now accompanied by Francisco Molina, continued the search for sites. His archaeological survey was running smoothly and gave every indication of continuing to do so.

Before the season was out we had been visited by Carmen Cook de Leonard, who had offered to do ethnohistorical research for us, and by Irmgard W. Johnson, who had volunteered to analyze archaeological textiles.

Excavations at the several sites ended in early June. During the summer Smith began the proposed botanical survey. During the summer also, with considerable help from Douglas Byers and Frederick Johnson, I prepared a report of our first season's activities which was published by the R. S. Peabody Foundation.

The second season began in December 1961. Except for a Landrover station wagon, a wide-carriage typewriter, materials for visiting consultants, and replacements for digging equipment and art supplies, the expedition acquired few new items. We did, however, convert the large front room of our headquarters into a laboratory with shelves, drawers, large tables, lights, and other necessary equipment. Miss Nelken and Angel García returned to work with us again. Narciso Tejeda had mastered the intricacies of our cataloguing system, and he carried on this duty leaving Toni Nelken free for other work.

At the beginning of our second season Peterson showed me sites that he had found during the summer. We also found some promising caves in Tecorral Canyon and the Arroyo Lencho Diego, in which Purron Cave is located. By this time Peterson's survey was producing an average of two new sites a day. My main activity during this period was testing the likely caves and sites with six of the past year's "El Riego" crew. Testing usually consisted of digging a trench one-meter wide and as deep as the deposit of refuse across the part of the cave or site that appeared to be best stratified. We tested six caves in Tecorral Canyon, three at El Riego, one at San Andres, four in the Arroyo Lencho Diego, and one near Coxcatlan Cave. We also sank two tests in the open site near Ajalpan. By the end of January we knew what we had to excavate and where we were going to do it.

Toward the end of January, Angel García joined me. In Tecorral Canyon we started excavations in two caves, and the work was finished by mid-February. We then commenced digging in Purron Cave, where García completed the initial excavations in late March.

The excavation of Coxcatlan Cave resumed in late February, when Fowler returned. For a time Miss Nelken acted as his assistant, but he was subsequently assisted by Robert Chadwick, then a student at Mex-

ico City College, and Arturo Arvide, a student of archaeology at the Escuela Nacional.

Visitors to Tehuacan that winter included Frederick Johnson and Mrs. Johnson. They joined the expedition for the purpose of collecting charcoal for radiocarbon dating. Mrs. Johnson spent much time concentrating the charcoal in the samples. Johnson instructed the staff in techniques of collecting charcoal in order to keep it free from contaminating impurities. Next came Thomas Whitaker and Hugh Cutler to collect modern *Cucurbita* and begin their studies of our archaeological specimens. Their work continued into March, when they returned to the United States. The Johnsons left about the middle of the month. Eric Callen arrived in Easter week to undertake analysis of coprolites found in the excavations and was occupied well into May.

In March we were joined by Douglas Byers and Mrs. Byers. Byers was concerned with the planning of our research program and the preparation of a general routine for contemplated publication. When Peterson and I undertook the excavation of the stratified Formative site near Ajalpan, the Byers were of great assistance. Indeed, Mrs. Byers excavated with painstaking care most of an important bell-shaped burial pit.

At Ajalpan there are several kilns where tile is manufactured. The mining of clay for these tile factories has exposed a number of archaeological deposits in the flat which lies just west of the town. The location at which we started working became known as the Ajalpan site, or Ts 204, and nearby was the bell-shaped burial pit, which we called Ts 204 C. Ts 204 A, B, D, and E were small excavations subsidiary to the larger Ajalpan site.

Through April our campaign moved ahead rapidly. Peterson and I worked at Ajalpan with a steadily augmented crew which finally reached twenty-five, while Fowler, with the help of Chadwick and Arvide, continued to work in Coxcatlan Cave and started excavation of the open site known as Coxcatlan Terrace just outside the mouth of the cave. Late in April, Arvide and I began the excavation of Abejas Cave, located near Purron Cave in the Arroyo Lencho Diego. We then undertook to prepare Purron Cave for Angel García's return.

In May, Peterson, helped late in the month by Arvide, continued testing stratified Formative sites, among them Ts 204 D and E, Ts 367, Ts 368e, and Ts 368w. Angel García finished excavations in Purron Cave by the end of the month. During the last week of May, Chadwick was assigned the task of finishing the excavation of Coxcatlan Cave, a job estimated to take three or four days. However, important features kept turning up, and the job took five weeks. With the completion of this work our principal excavations were brought to a close.

These few months of 1962 were the most exciting of my life. I would like to digress for a moment, to indicate how the days were spent, and give some idea of their pace. We were up at dawn. Breakfast. The scramble of getting equipment for each dig into the right truck. Workmen milling about. Suddenly it was seven o'clock, and three trucks loaded with workmen and equipment erupted from headquarters and drove off to the digs.

On days when I did not go to one of the digs, I breathed a sigh of relief, took a second cup of coffee, and went to check the cataloguing or visit the laboratory. All too frequently the cataloguers were in the process of washing a new and exciting find. Although I had not intended to linger, I would stop to look at it, and then at others. This often took me to the library to see whether I could find published accounts of similar finds from other regions.

In the laboratory Toni Nelken might have an artifact sequence laid out on the table for my inspection. Or we might start a new chart, plotting types against levels. Our work was so absorbing that before we knew it lunch time was on us.

The kitchen, spick and span since the chaos of breakfast, was usually filled with the fragrance of freshly made soup, concocted by Lupe and Angelita. When we were lucky enough to have a visiting scientist with us, the lunch hour would be given over to discussion of aspects of his work. Or there might be general discussion of happenings of the day. The mail, newly arrived, often brought news of another visitor, inquiries or congratulations on some new find, or perhaps news from Johnson about a radiocarbon date that could cause Fowler to direct greater efforts to a particular part of Coxcatlan Cave.

The hours after lunch passed as quickly as the hours before. Suddenly Narciso and "Ratón" would pass the laboratory window; it was three o'clock and their work day was done. But not ours. Toni Nelken and I would continue our efforts, perhaps experimenting with a new method of analyzing artifacts or continuing the endless measuring, recording, and comparing of their many attributes.

Why had a truck come back early? It's not early. The afternoon is gone. First comes Peterson in the jeep. The hustle and bustle of unloading and shouted

news of some minor triumph might be followed by careful unwrapping of a special find. Next would come Fowler in the Landrover, and there would be more unpacking, more things to see, and more discussion. Then García would come in, and the whole business would be repeated.

A "sundowner" at the Hotel Peñafiel or on the plaza would give us a chance to continue our discussions of the day's finds, or of possible improvements in ways of digging, or of whether I should visit one of the sites, perhaps to help determine stratigraphy. The move to the kitchen for Lupe's delicious supper could hardly interrupt our excited talk. Nor did jokes or bad puns affect us.

More work in the lab to finish the afternoon's tasks, or perhaps to shift the artifacts on the table, followed dinner. We might try using chi-square for detailed inspection of artifacts in order to find new attributes. Before I knew it Toni Nelken would be gone. I would stumble to my room, slip off my clothes in the pitch black, and fall into bed wondering why I stayed up so late when there was so much to be done tomorrow.

The next day would start the same way, but I would be lucky enough to be on one of the trucks going out to the digs. Perhaps I intended to coordinate laboratory and field findings or just see a new feature, but before I was aware of it I would be busily at work with a trowel, brush, and notepad. And then it would be lunch time, even for me. Lupe with her usual foresight had put in food for me, and my tacos would join those of the others in the hot coals when the cry of "Lumbre!" would bring our work to a halt. It would be impossible to tear myself away after lunch. There would be a burial or other feature to see, the boundary of a zone to follow on a newly cleaned profile, or a certain point type discovered in an unexpected zone. And suddenly it would be time to go home. Then we started through the whole business again—unpacking, discussions, comparisons. And so it went for two—almost three—months.

In June, however, the excitement died almost as quickly as it had begun. Callen, Nelken, Chadwick, and I departed early in the month, leaving Arvide and Peterson to finish the work at Coatepec and Quachilco.

Kent Flannery appeared in July, and at once set about collecting samples of the modern fauna. This task occupied him into August.

In late August the XXXV International Congress of Americanists convened in Mexico City. Once again some of our group assembled—this time to make preliminary reports of our findings. Those reporting included Byers, Fowler, García, Nelken, Peterson, Smith, and myself. After the Congress a number of delegates came to Tehuacan and were taken on tours by Smith, Peterson, and Byers.

In September, Lawrence Kaplan came down to make a careful study of the beans found in our excavations. At about the same time Flannery came back and resumed collecting fauna. Some months later he began to analyze faunal remains from the excavations in light of his newly made collection of modern fauna.

December 1962 brought a larger group, and we began the analysis of our findings. Paul Mangelsdorf, accompanied by Mrs. Mangelsdorf, and Walton Galinat came from the Botanical Museum of Harvard University to study close to 23,000 pieces of archaeological corn. With some assistance from Edward Wellhausen and William H. Hatheway of the Rockefeller Foundation, they were able to complete preliminary studies by early January.

In January 1963 we were joined by Miss Mary Hill Gilbert, who was to be our secretary, and by Miss Nancy Hansen, who at once took over the duties of expedition artist but waited three months before taking over uxorial responsibility as Mrs. Kent Flannery.

Frederick Johnson returned in February with the object of collecting radiocarbon samples from the Formative sites known as Ajalpan, Las Canoas, and Coatepec, and from a few others for which we had only inadequate samples. By this time Flannery had segregated certain bones found in the lowest levels of Coxcatlan Cave and had tentatively identified them as being from animals now extinct in the valley. When his identifications were confirmed, Johnson took over the responsibility for these levels. He found additional artifacts associated with bones of extinct animals, and he found charcoal as well. His painstaking care in excavating these zones produced evidence of disturbance by rodents, and evidence suggesting that the charcoal found near the bones and artifacts had entered the zone through rodent burrows. It thus was not in clear association with the finds and was of no value for establishing the date of occupation.

Other visitors included Robert J. Drake, who came to study shells collected in the excavations, and James Schoenwetter, who came to collect pollen samples and discuss the possibility of ecological studies in conjunction with the archaeological program.

The Byers paid us a brief visit in April, at which time Byers and I discussed plans for publication and for preparing the final reports. He and I set out during

a few days when there was comparative calm at headquarters to survey the area above Xaco, near Chilac, to see if we could enlarge our sample of preceramic open sites. We found what we took to be a pit-house village, and some months later, we succeeded in uncovering remains of one complete pit house and evidence of others that had been badly damaged by erosion. Byers subsequently undertook excavation of what we took to be a pit house, only to find that it was the remnant of a silted-up irrigation ditch.

The season came to a close in June, but the next season opened in August when I returned to Tehuacan in the company of Callen and Smith to study the remains of plants. In this work we were assisted by Miss Gilbert, Miss Nelken, and Narciso Tejada.

After this work was completed, I became involved in the preparation of an application for funds for preparing the manuscript and in writing and preparing for publication a second annual report. In mid-November Peterson departed for a new job, leaving the laboratory and household running smoothly.

The final season, which began in December 1963, was devoted primarily to analysis and reporting of our finds. In this work I was assisted by Miss Ann Harvey, a Bennington student who had training in both botany and archaeology, and Miss Elizabeth Trull, a new secretary. Unfortunately, Miss Trull's work on our manuscript was terminated when she was injured in an automobile accident.

In January 1964, James Anderson arrived to study the skeletal remains from our digs. In February, Richard B. Woodbury and Mr. and Mrs. James E. Neeley joined us. As our field research progressed, we had observed numerous signs that irrigation had been practiced in the Tehuacan Valley in ancient times. We were fortunate in persuading Woodbury, a recognized expert on arid land, to undertake studies of this aspect of prehistoric life. Results of his studies will appear in a later volume.

After Woodbury returned to Washington, James and Mary Ann Neeley stayed on in Tehuacan to make a survey of irrigation features. They not only found many "fossil' irrigation ditches preserved by salts carried in the water, but to our great surprise, discovered in the Arroyo Lencho Diego remains of a huge dam—over which we had driven every day going to and from work at Purron and Abejas caves. There were also remains of several aqueducts and other ambitious engineering projects undertaken to bring water to the fields. In order that the study of irrigation features might be interpreted in terms of modern practices, Aubrey Williams has undertaken a thorough study of modern irrigation practices.

In late February we were again visited by Mr. and Mrs. Johnson, Johnson having come to take first steps leading toward a final correlation of radiocarbon dates and cultural remains. They left about the same time Miss Paulina Heard arrived to take Miss Trull's place as secretary.

Concomitant with and often directing our field operations was the analysis of the archaeological and environmental data. The analysis was of two general sorts; that done in the field with specific reference to digging and survey procedure and that done by visiting scientists on material that had been excavated in order to help us achieve a more complete archaeological, environmental, and chronological reconstruction.

Preliminary classifications and cataloguing of our specimens had begun almost as soon as we gathered them. One of the first duties of Toni Nelken when she joined the expedition in April 1961 was to devise a general cataloguing system. However, within a short period her work with the classification of stone artifacts came to demand so much of her time that she was forced to turn over the cataloguing of the collection to Narciso Tejada. During the following summer he was assisted by Francisco Molina and R. Pérez, and during the final stages of 1963 Augustín Tejeda joined this group. Initially, they washed, numbered, and classified into general categories the materials uncovered, but by 1963 they had become so skilled that they made the actual counts of the different types from most of the surface sites.

The classification of stone artifacts was begun in the spring of 1961 by Toni Nelken and myself, and she was able to complete a preliminary classification of all of the excavated stone artifacts by the beginning of our second season. The artifact trends shown by this study indicated definite gaps in the sequences in our first two excavations, and this information became a determining factor in the selection of sites for excavation in the 1962 season. In that year, as stone artifacts were uncovered, we modified our preliminary classifications and aligned our excavated components into chronological order on the basis of these classifications. In 1963, with the help of Mary Hill Gilbert, we wrote our first draft describing the artifacts. In 1964, the stone artifacts from surface collections were incorporated into our report. Except for the report on textiles contributed later by Irmgard Johnson, the drafting of Volume II was almost completed by the time we left the field.

Formal pottery classification was started in the summer of 1962. When we were making the preliminary survey and during our testing in 1962, Peterson and I had roughly sorted the surface collections into general periods. Peterson began by sorting some of the Postclassic pottery, and later classified early Formative (Ajalpan) ceramics. At about the same time he was doing this, Kent Flannery undertook a preliminary classification of middle Formative sherds. In 1963 I undertook a classification of the sherds of the Formative period from the Coatepec site. Later Peterson studied the Quachilco remains, and all three of us attempted to co-ordinate our classifications. The final classification of sherds was carried out in 1964 under my direction, with the help of Ann Harvey, Mary Ann Neeley, and the cataloguing crew. The fine perrographic study of Arturo Sotomayor was incorporated into our reports at this time. During the late spring of 1963 José Luis Lorenzo had put us in touch with Ingeniero Sotomayor, who was then working with the laboratory of the Departmento de Prehistoria making thin sections of pottery for the purpose of identifying minerals. We anticipated that studies of this sort would be of great value in connection with the analysis of the Tehuacan pottery.

In June 1964 we also assembled a field conference to discuss early Mexican pottery. This was attended by James A. Ford, Matthew W. Wallrath, and Alfonso Medellin Zenil, all of whom had been working on the coast of central Veracruz; Robert Squier, who had worked on the coast of southern Veracruz and Tabasco; John Paddock, who was familiar with the pottery of Monte Alban; Melvin L. Fowler, who was at that time working near Puebla; Kent Flannery, who had worked on the Pacific coast of Guatemala as well as in Tehuacan; and Bruce Warren and Gareth Lowe, who had just completed their study of the pottery of central Chiapas. This conference produced significant information regarding the distribution of types of pottery found in the excavation of the Tehuacan Valley.

Thus, again by the time we left the field, we had at least tentative descriptions of most of the ceramics and the bulk of our third volume in rough draft, even though it was not readied for publication until some time later.

One of the final steps of the field analysis took place in 1964 when James Neeley and I attempted to analyze the data from the 454 sites found in the archaeological reconnaissance. Obviously such a study had to await the classification of all the stone, bone, shell, and perishable artifacts as well as the ceramics. Once these remains had been classified, the sites aligned in chronological order, and their cultural phase determined, we began an analysis of the survey material to determine changes in settlement pattern and population. A resurvey of many sites carried out by Neeley at this time contributed greatly to our understanding of settlement patterns. I was able to complete a study of the preceramic sites and Neeley the Formative sites before the field season closed. Neeley's final analysis of the Classic sites and mine of the Postclassic sites were completed later.

The preparation of site reports involved processes analogous in many ways to the foregoing. Although a description of excavation could have been made immediately at the termination of each dig, reconstruction of the way of life and the environment at the time of each occupation of each site had to await data from several sources. By the 1964 season, however, we did have studies of all the artifacts from every floor, as well as a considerable number of studies of special materials from these floors. As all these data became available we began to correlate them, and Fowler started to write his site report on Coxcatlan Cave. Using the field notes as well as data assembled by Ann Harvey from many sources, I began preliminary drafts of reports on San Marcos, Tecorral, El Riego, Purron, and Abejas caves.

At a dinner held at the Hotel Peñafiel in April 1964 all the findings of the Tehuacan expedition were presented to Dr. Ignacio Bernal, Director of the Museo Nacional de Antropología, for the people of Mexico, by Mr. Byers, acting on behalf of the Tehuacan Project, the Robert S. Peabody Foundation, and the Trustees of Phillips Academy. The formal presentation was made at this time because many of the persons involved would have found it impossible to be present when the Tehuacan project came to a close in August. The actual transfer of specimens occupied several weeks during the summer.

In June Dr. Anderson returned to complete his study of the skeletal material. At about the same time Jean Brunet undertook a study of the geology of the Tehuacan Valley.

July 1964 was the beginning of the end. Although we were working feverishly to finish the analysis of some of our material, we nevertheless began to ship our excavated specimens to the Museo Nacional in Mexico, to send materials gathered by the site survey to the Museo de la Revolución in Puebla, and to set some specimens aside for a museum to be established in Tehuacan.

August saw us packing, selling the furniture and equipment or giving some of it to friends and employees, and making one thousand and one final ar-

rangements. Then suddenly, on August 20, the house was empty. The Tehuacan field project was over.

This brief summary relating how so many people contributed to making the Tehuacan project a success will, I hope, serve as a way of thanking all of them. When I wrote it, it seemed a better way of expressing my gratitude than the usual dull acknowledgments with a thank you to a long list of names. I have, I am afraid, omitted some of the many Tehuacaneros who helped us and to whom, again, I owe much. In conclusion, let me say that all of us who participated in this expedition worked very hard, struggled to keep to an impossible schedule—necessitated in some respects by my own compulsive neurosis as well as by the usual shrinking exchequer—and in many cases pushed ourselves to do a little better than our best. Thus I would like not only heartily to thank my colleagues, but also to ask their forgiveness.

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CHAPTER 1

An Interdisciplinary Approach to an Archaeological Problem

Richard S. MacNeish

THE IMMEDIATE objective of the Tehuacan Archaeological-Botanical Project was the establishment of an uninterrupted archaeological column spanning the time between the first human occupation of the valley and the Spanish Conquest. This hoped-for archaeological column would almost certainly be divisible into cultural phases, representing progressively more advanced societies, culminating in civilization. Thus we should, in effect, recover a sequence of cultures, which we assumed might be representative of developing civilization in Mesoamerica, one of the major culture areas of the world (Kirchhoff 1952). This sequence we could then compare with similar developments in other areas, and by thoroughly studying and classifying the various features of each, determine the reason that each unit came into being (Steward 1955). Thus the ultimate objective of the Tehuacan project was the discovery of processes and causes leading to the rise of primary civilization. In order to attain this end we would require several sequences of culture in relatively independent areas, each leading to civilization.

Our assumption that the sequence from the Tehuacan Valley would be typical of Mesoamerica was based on two bodies of data derived from previous research. First, the region is centrally located in Mesoamerica. Previous investigations on all sides of it had revealed sequences of development from early villages to urban civilization. To the northwest, in the Valley of Mexico, a relatively complete sequence beginning with the Zacatenco villagers of about 1000 B.C. led to the city-dwelling, empire-building Aztecs (Vaillant 1966). To the northeast, sequences in central Veracruz (Medellin Zenil 1960) and northern Veracruz (Ekholm 1944, MacNeish 1954) exhibit developments from villages to cities. To the southeast, the early Olmecs developed toward a civilization in southern Veracruz and adjacent parts of Tabasco (Drucker 1943). To the south was the sequence at Monte Alban in central Oaxaca (Caso 1938), while even further south, in the Mayan region, were a number of sequences from folk to urban culture (Kidder, *et. al.*, 1946).

Second, we had assumed that the rise of civilization was intimately connected with the development of agriculture. In the New World and Mesoamerica, agriculture, we believed, depended on the domestication of corn, *Zea mays*.

The origin of corn was one of the major puzzles of New World botany and archaeology. Various hypotheses had been advanced to explain the existence of this grain which, unlike the Old World grains—wheat, barley, rye, oats, and millet—had no identifiable wild ancestry, but none was truly satisfactory. In the Introduction we recounted, in detail, the series of steps by which the regions to be searched for the origins of this important cereal were narrowed by eliminating first Asia and then South America as possible centers, and next how the northern limit of the target zone was carried southward from New Mexico, through the Mexican states of Tamaulipas, Sonora, and Chihuahua to the Valley of Mexico. Discovery of pollen identified as that of maize at a depth of some seventy meters in a drill core from Mexico City made plant geneticists aware that the ancestor of corn was corn itself, and that corn was not developed from *teosinte* or *Trip-*

sacum, or a cross between them. As this pollen came from levels attributed to the Yarmouth interglacial, it cannot be connected with human activity and is presumed to be that of wild maize. Other pollen, abundantly present in upper levels, is judged to represent cultivated corn (Barghoorn *et al.* 1954).

We have also told in the Introduction how excavations in Santa Marta Cave gave us reason to believe that the original homeland of corn lay north of Chiapas and how Mangelsdorf and I ultimately confined the area in which to concentrate the search to the Tehuacan Valley. When preliminary testing in Coxcatlan Cave produced cobs of primitive corn that were dated to 3610 B.C. ± 250 years (M-1089, Crane and Griffin 1962), it was clear that the Tehuacan Valley, more than any other spot yet tested, gave promise of supplying an answer to this problem.

In order to obtain, in Tehuacan, a complete sequence of culture representative of that in Mesoamerica and of use in wider comparison, two basic problems had to be solved—the cultural chronology had to be determined and cultural contexts had to be established. Perhaps I should say that we had to reconstruct ancient cultures and their environments throughout our sequence. At times we studied both problems together, but we preferred to study chronology before we turned to interpretation, because we felt the latter could not be truly understood unless the former was known.

In attacking these problems, we used an interdisciplinary approach, bringing to bear upon the solution of our rather specific archaeological problems facts or conclusions from a number of scientific fields, derived from an even wider range of techniques and methods. Thus the project, instead of relying on one kind of evidence derived from a single line of research with its peculiar set of techniques, made use of many kinds of evidence from many directions, all leading to the solution of our problems.

Needless to say, the so-called facts of the various disciplines must be derived by a careful and well-executed set of field and laboratory techniques. This is particularly true of archaeology and our techniques will be described in some detail in the following chapter. Mainly because of the careful application of these techniques we were able to attack successfully the wider problems with a great mass of data. From many standpoints, our techniques were unique for Mesoamerica. This is an area where great designs for research often have been defined, but rarely implemented successfully. This, I believe, is because well-designed superstructures often sit on a poorly laid foundation, built with rather inadequate techniques.

Now let us turn again to one of our basic problems. In order to establish a chronologic arrangement of the cultural units we had discovered, we resorted to a variety of methods, some of which established a relative, but not very precise, chronology, while others established a more precise chronology. Regardless of whether the resulting chronology was relative or precise, we relied on a number of methods from a number of fields of endeavor, using a wide range of techniques. We brought all to bear on a single problem—chronology.

One method for establishing chronology relied on stratigraphy. We chose for excavation those sites which would give the maximum amount of cultural stratigraphy. We dug a total of sixteen pits and uncovered in them a total of 156 occupational layers, or zones, as we shall call them.

Each zone we considered to be a distinct deposit, laid down during a single interval of time. Usually each zone was relatively uniform in color and in content, whether it was ash, roof fall, waterlaid sands, clay, or other material, and each zone was capped by a well-defined stratum or break in the soil profile. This stratigraphic discontinuity might consist of a charcoal floor, a layer of vegetal material, a tramped dirt floor, or other matter, but it definitely marked the end of the period of deposition of refuse in the zone beneath.

Coxcatlan Cave (Tc 50) was our best stratified site, for we identified there 28 zones. Each of the lower zones, XXVIII-XXV, consisted principally of an irregular stratum of fallen rock and wind-blown sands, and each was capped by a thin charcoal floor in a small central portion of the cave. It should be noted that Zone XXVIII, capping the base level of the cave, was without artifacts but did contain animal bones. Zones XXIII and XXIV were layers of ash and/or fine dirt or silt capped by well-defined charcoal floors in portions of the west end of the cave. Zones XXII to XIX were similar, but covered small areas in the east end of the cave. Zones XIV-XVIII, and Zone XI as well, were also ashy layers, but they extended over the entire area of the cave and were capped by charcoal or burned floors with ever-increasing amounts of preserved vegetable remains. Zones XII and XIII were of similar content in the west end of the cave, as were Zones VIII, IX, and X in the east end. Zone VII represented a break in the sequence, as it was an all-encompassing layer of vegetable remains. Zones I to VI were floors of vegetable refuse over ash or disintegrated rock. The top zone was a layer of goat dung, refuse not directly made by man.

The zones in the East Niche of El Riego Cave (Tc

35e) were very similar in makeup to the upper zones of Coxcatlan Cave. Zones C-E were ash layers capped by floors of preserved refuse that extended over the whole surface area of this small cave. Zone B was a layer of ash and vegetal material and was capped by a plaster floor. Zone A consisted of a layer of vegetal material above the plaster floor, and it, in turn, was capped by goat dung.

The stratigraphy in Purron and Abejas caves resembled the lower zones of Coxcatlan Cave, in that there were rather thick layers of fallen rock, sand, and finer sediments, capped by recognizable floors composed of charcoal, vegetal remains, or burned material. The earliest thirteen of the twenty-five zones in Purron Cave (Tc 272), Zones L-U, covered small areas, measuring approximately 5 by 8 meters, in the southwest part of the cave; the occupational floor capping each zone comprised chiefly charcoal. The upper twelve zones, A-K, were capped by floors of charcoal and vegetal remains, laid down over the entire surface of the shelter.

In Abejas Cave (Tc 307) there were eleven zones, all of limited extent, and all but the uppermost capped by charcoal or ash. The upper Zone A included vegetal remains. The top layer consisted of a capping of goat dung.

San Marcos Cave (Tc 254) was small. In it, the five zones, B-F, were comprised of small flakes of fallen rock overlain by thin layers of vegetal remains. Refuse in the rock fill of Zone C caused it to be designated a separate layer; the charcoal floor above it was recognized as a separate zone and called C^1. The uppermost layer, goat dung, was identified as Zone A.

Tecorral Cave (Tc 255), next to San Marcos Cave, was even smaller. A small floor of charcoal and vegetal remains at the top of the deposit was designated Zone A. It apparently represented a short occupation of the cave. Below it was a floor of ash from which a pit extended downward. Together they constituted Zone B. Although no clearly defined floor was seen below Zone B, the rock fill with artifacts that extended down to the base rock of the cave was designated Zone C.

The stratigraphy in the West Niche of El Riego Cave (Tc 35w) was even less clear, and the floors capping its six zones were less well defined. The lowest occupation layer, Zone 6, covered only four or five square meters. It lay directly on the bottom of the cave and was readily discernible as a thin layer of ash and charcoal. A layer of dark refuse covering about twice the area, and lying above Zone 6, was called Zone 5. The upper margin of Zone 5 merged gradually into a zone of brown refuse, Zone 4. A layer some 15 cm. thick including the transition from Zone 4 to Zone 3 was peeled off and designated level 3–4. Above this was a deposit of brown refuse that we divided into three zones: the top zone, 1, above a charcoal plaster floor; a second layer, Zone 2, from which graves and grave pits could be traced downward; and the lowest, Zone 3, composed of refuse beneath the burial pit.

At the open sites less clearly defined floors capped the zones. Perishable materials were not found in them, and conditions at these sites therefore differed from those encountered in caves. The site known as Coxcatlan Terrace (Ts 51), below Coxcatlan Cave, was capped by Zones A and B that differed only slightly in color and appeared to have been formed by material dumped down the talus from the cave above. They covered stream-deposited sediments called Zone C. Beneath this was a burned layer forming a charcoal floor labeled Zone D. Zone E consisted of a thin layer of refuse beneath Zone D. These zones, like those in the other open sites, were only tested. Undoubtedly they covered much of the terrace in front of Coxcatlan Cave.

The other open sites that we tested were considerably larger. Coatepec (Ts 368), was more than 200–300 meters long by 100 meters wide. Refuse was very deep and appeared to have been laid down in a short time. In the deepest trench at the east end of this site (Ts 368e), we recognized 18 layers. All but the three lowest were composed of dark lenses of refuse and earth capped by floors. The lowest layers, K^1, K^2, and K^3, were arbitrary divisions of a rather deep layer of refuse. Zone D near the top also had from one to three charcoal floors, and although they actually comprised three zones, because of the paucity of artifacts in each they were usually combined for purposes of analysis. A smaller test at the west end of the site (Ts 368w), disclosed only five zones, A–E, which were refuse-capped floors that had abutted against a small pyramid and eventually covered it completely.

At Quachilco (Tr 218) there were similar layers of refuse capped by floors. There were six such zones in Test 10, seven in Test 11, and eight in Test 6.

Conditions at Las Canoas (Ts 367) were slightly different in that the two top zones, A and B, were thick strata of refuse, Zone A being dark brown and Zone B light brown. Above these strata, laid down during the final Venta Salada period, we recognized no floors. Below Zone B was a recognizable charcoal floor over a little sandy refuse designated Zone C. Below that was Zone D, a thick layer of charcoal covering a layer of

refuse designated Zone D^1, which covered sterile soil.

At the Ajalpan site (Ts 204), with ten layers of refuse, conditions resembled those at Las Canoas. Here again, Zones A and B were refuse, light brown and dark brown respectively, extending down a meter from the surface. Zones C and D were waterlaid sands containing some refuse. Zone E below them was a zone in which there was charcoal. Next came Zone F^1, a hard-burned floor capping rather a small thin layer of burned refuse, Zone F. The latter covered a burned floor with pits extending down to it, Zone G^1 over refuse Zone G. At the very bottom of the site, above sterile soils, was Zone H, a thin charcoal floor representing a relatively short occupation.

Another part of the same site was designated Ts 204 D. Here again there was at the top a layer of undifferentiated refuse, Zone A-B. Beneath this refuse came Zones C and D, also refuse, but with some sand content. A definite floor (Zone Super-E or E^1) overlay a stratum of refuse called Zone E. This, in turn, rested on refuse, Zone Sub-E, that capped the sterile clay of the vicinity.

The various zones described above represent closed intervals of time during which people laid down refuse and sediments built up. These also were the temporal units of occupation or the components that became the basis of the stratigraphic sequence of cultural materials and cultural phases in the Tehuacan Valley.

These 156 components of the stratified sites revealed cultural chronology by reason of changes in their contents, comprising in round numbers 250,000 artifacts of clay and 13,000 of stone, 25,000 remains of domesticated plants, and 70 human burials. No single site we excavated yielded the full sequence. Furthermore, studies of the actual strata by visiting geologists and soil scientists revealed no method for correlating zones of one site with those of another. Studies of 11,000 bones of animals, 25,000 molluscan shells, and 80,000 remains of wild plants, all taken from excavations, gave hints of the alignment of the various zones, but were not sufficiently sensitive in our region to aid in establishing a relative chronology. We had hoped that pollen studies might add to this aspect of the research, but the pollen was too poorly preserved.

Perhaps the best means of establishing relative chronology was by the taxonomic method, using material from the stratified sites. Assumptions, techniques, and applications of this method, as we used it, will be fully explained in Volumes II and III. Suffice it to say here that this method depends on isolating artifact modes—those attributes of an artifact which are so sensitive to changes in tastes and habits of work that they themselves undergo slight changes—and that a proper identification of artifact modes will reveal cultural change and trends.

Initially, we established artifact types on the basis of mode clusters—series of interrelated features of artifacts having significance in time and space. We first determined artifact types and trends for the rich stratified site in Coxcatlan Cave, Tc 50. By using trends of artifact types from Tc 50 as a standard with which we could compare artifact types from other stratified sites, or for that matter, from sites represented only by surface collections, it was possible to correlate any other site provisionally with the sequence in Coxcatlan Cave, assuming that a zone or component was probably closest in time to that zone in Tc 50 with which it shared the greatest number of artifact types. As a result of our studies of types and sequences of artifacts from the 156 excavated components and approximately 350 surface sites, we were able to align all in relative chronological order (see Table 32, Volume II, and Volume IV).

Typology, besides making it possible to describe artifacts and assisting us in aligning the archaeological components in order of relative chronology, also served to define the actual components. Needless to say, some archaeological components fitted into the sequence more easily than others, and some could be more easily defined than others. A component represents the occupation of a place during a single continuous unit of time by a single cultural group. Because some components were less easily defined than others, we divided all the components among three categories: pure components, probable components, and possible components. By a pure component we mean a zone which is so well defined physically that it could only have been occupied for what is considered a single moment in time, and which contains enough artifacts so that we may feel sure that it represents only one cultural group. Probable components are those whose physical features lack sharp definition or whose inventory of artifacts lacks a sufficient number of diagnostic types so that we cannot with certainty say that they represent a single occupation by a single cultural group. Sites or zones termed possible components have even more limited complexes of artifacts or less distinct evidence of occupation, so that it is only barely possible that they were occupied by one group at one time.

Another kind of taxonomic study, that of remains of domesticated plants from the sixty excavated components in which preserved food stuffs were found, con-

firmed at least part of the sequence of components based on artifact typology. Races of corn determined by Mangelsdorf and Galinat allowed them to align in chronological order Zones I-XIII of Tc 50, Zones B–F of Tc 254, Zones A–K of Tc 272, Zones A–E of Tc 35e, and the top zones of Tc 307, Tc 35w, and Tc 255. Kaplan's study of the beans demonstrated parallel sequences and a study of the cucurbits by Whitaker and Cutler confirmed the order established by the corn and also helped to establish the position of Zone XIV of Tc 50. Smith's study of other domesticated plants produced results in harmony with the relative position of components revealed by the foregoing plants.

Thus, our relative chronology was established on the basis of stratigraphy, artifact typology, and the developmental sequence of domesticated plants. We attempted to supplement our data on chronology with studies of the hydration of obsidian. Although this technique seemed to offer promise (Friedman and Smith 1960; Evans and Meggers 1960), painstaking studies by Dr. Donovan Clark failed to substantiate its value as a gauge of time in the Tehuacan Valley.

Convincing substantiation of the relative chronology came from chronometric studies. After we had tentatively established the relative chronology, we carefully selected components to be dated by the radiocarbon method so that we would have dates representing the entire sequence. All told, we obtained over 120 radiocarbon dates for sixty-two of the 156 components. As a result, no period of over 500 years in the last nine millennia is without at least one radiocarbon date. The results completely confirm and substantiate the ordering of the less precise relative chronology. Further statistical study of the artifact sequence in all components in conjunction with the radiocarbon ages of the selected components made it possible to estimate the ages of the undated components. This analysis, like that of the relative chronology, will be fully explained by Johnson and MacNeish in Volume IV.

Dates mentioned in this and the two succeeding volumes are used only as rough approximations and may have a range of error of as much as 500 years either way. We have used approximate dates in order to give the reader some temporal orientation, since the first three volumes were written before analyses for Volume IV could be completed.

We employed still another method—cross-dating—to make our dates more precise. Our studies of artifact types at once revealed objects—mainly potsherds—brought to the Tehuacan Valley from outside sources. Those artifact types whose position in the cultural sequence of their native regions was well established by radiocarbon dates served to place in time the zones in the Tehuacan Valley in which they were found. Dates from other regions could thus be applied to the sequence in the valley. In cases in which we had a radiocarbon date for a zone in which a "foreign" object was found, it could be used as a measure of correctness of our date. In cases in which we had a number of confirming dates in the Tehuacan series, they could be used as a measure of correctness of the "foreign" dates. The same may be said regarding types native to the Tehuacan Valley which were identified in sequences in other regions. Such cross-dating not only confirmed the relative chronology but supported the validity of our series of radiocarbon dates, particularly in the case of dates for the later phases when pottery was plentiful.

All in all, our sequence of components, established by making use of the methods and techniques of several disciplines, appears to be based upon a fairly firm foundation. Obviously, the sequence would be improved by larger numbers of artifacts or remains of plants or animals from certain segments, by more radiocarbon dates, and by thorough mineralogical studies of trade objects, along with more and better radiocarbon dates to place these objects beyond question in the time scale of their native region.

Comparison of artifact types and related data from each component not only yields chronological information, but also information on another level of abstraction. For instance, comparison of our regional artifact types with those of other regions could yield information not only useful for cross-dating but also for determining spatial relationships, such as the origin and spread of these artifact types.

In addition, comparison of the various components with each other and with clusters of artifact types within the Tehuacan sequence allowed us to discern major and significant periods of culture change. This latter process revealed that there were eight spurts or clusters of new artifact types and other diagnostic traits in our long relative chronology, rather than just gradual accumulations of new assemblages. We believe these spurts represent periods of significant cultural change. The periods or segments of our sequence which have new complexes of types recurring in a number of sequential components are designated "phases." Our actual comparison of artifact types and other traits from each component from Tehuacan revealed nine phases that we called, from early to late, Ajuereado, El Riego, Coxcatlan, Abejas, Purron, Ajalpan, Santa Maria, Palo Blanco, and Venta Salada.

Throughout these reports such terms as Early Man,

Incipient Agriculture or Archaic, Formative, Classic, and Postclassic are used. Obviously, this usage infers a further set of units of classification. I use these terms not as stages but as periods. The Early Man period would be before 7000 B.C. (in Tehuacan, the Ajuereado phase), the Archaic or Incipient Agriculture period would extend from roughly 7000 B.C. to 2300 B.C. (the El Riego, Coxcatlan, and Abejas phases), the early Formative period from about 2300 to 900 B.C. (the Purron and Ajalpan phases), the middle Formative from 1000 or 900 B.C. to about 600 or 500 B.C. (early Santa Maria phase), the late Formative period from before 600 B.C. to 200 B.C. or the beginning of the Christian era (late Santa Maria phase), the Classic period from before the time of Christ to A.D. 700 or 800 (the Palo Blanco phase), and the Postclassic period from A.D. 700 or 800 to the time of the Spanish Conquest (the Venta Salada phase). Let me state specifically that these terms are not meant to designate stages in a unilinear cultural development. I have considerable doubts that any sort of "unilinear" scheme of evolutionary stages led to civilization in Mesoamerica.

Although the phases of Tehuacan prehistory were defined primarily on the basis of artifact types and cultural traits, a full understanding of the culture each represented was obtained by a conjunctive or interpretive study using an interdisciplinary approach. Again, as in our interdisciplinary approach to chronology, we attempted to use information derived from a number of fields in our effort to reconstruct the ancient way of life of people who made the artifacts that we now classified into arbitrary divisions termed phases.

Studies of the geology and modern geography of the region suggest that the physiography and topography have not undergone drastic change since men first entered the valley. Geological studies, however, show that there has apparently been a continuous lowering of the level of ground water during that interval. Historical data, also, show that a marked reduction in effective water supply has occurred in at least one town within historic time. Geological studies hint at possible sources of raw material for aboriginal weapons, tools, or works of art.

We had hoped to be able to reconstruct past climates, or at least to point toward suggestions of possible changes in climate through studies of land snails and of pollen secured from our excavation. A study of snails was undertaken, but although preliminary results suggest slight climatic changes, it proved impossible to carry this work to a satisfactory completion. Pollen found in samples taken in 1961 led us to hope that pollen studies would be rewarding. Although James Schoenwetter, Elso S. Barghoorn, and Henry Irwin have worked on samples taken subsequently, none has been able to isolate a sufficient quantity of pollen from the earlier components to warrant any statements about stratigraphy. Pollen grains appear to undergo a progressive reduction in density with the passage of time, eventually disappearing. No pollen that is not representative of the present vegetation has yet been found in any sample. We are forced to conclude that the amount of pollen is insufficient and the number of species represented by preserved grains is inadequate to disclose a record of past climates in the Tehuacan Valley.

Studies of plant remains indicate no change in climate of any magnitude (see Chapter 12). Bones of animals from very early levels include those of several species now extinct or not represented in the Tehuacan Valley (see Chapter 8). It is possible to postulate the existence of a climate in early Ajuereado time that was slightly cooler than that of the present day, but corroborating data is lacking.

Detailed studies of micro-environments, including rainfall, drainage, exposure, and evapotranspiration, of soils and bedrock, of minute variations in temperatures, and of the plant cover that has developed in response to variations in these factors may someday be combined into a whole which will shed much-needed light on processes of cultural differentiation and specialization in restricted environmental niches and on processes of cultural evolution within one valley. We had hoped to take preliminary steps in this direction, but because necessary data were unavailable, progress along this road has not been either great or sure. Such environmental information as we have gathered is presented below in Chapters 3, 4, 5, 8, and 12.

In order to reconstruct the extent to which the prehistoric inhabitants exploited their environment it was necessary to utilize data derived from researches carried out by scholars from several disciplines. Their work, most of which is presented in this volume, covers studies of both wild and domesticated plants, including corn, beans, cucurbits, and other cultigens; the first published list of the fauna of the valley and an interpretation of the significance of remains of animals found in local archaeological sites; measurements and observations on such human skeletal remains as survived to us; research on physical and historical geology and hydrogeology; a consideration of the climate of the valley; and an examination of the developing practice of irrigation. An estimate of the actual sustenance of the ancient inhabitants is based upon interpretation

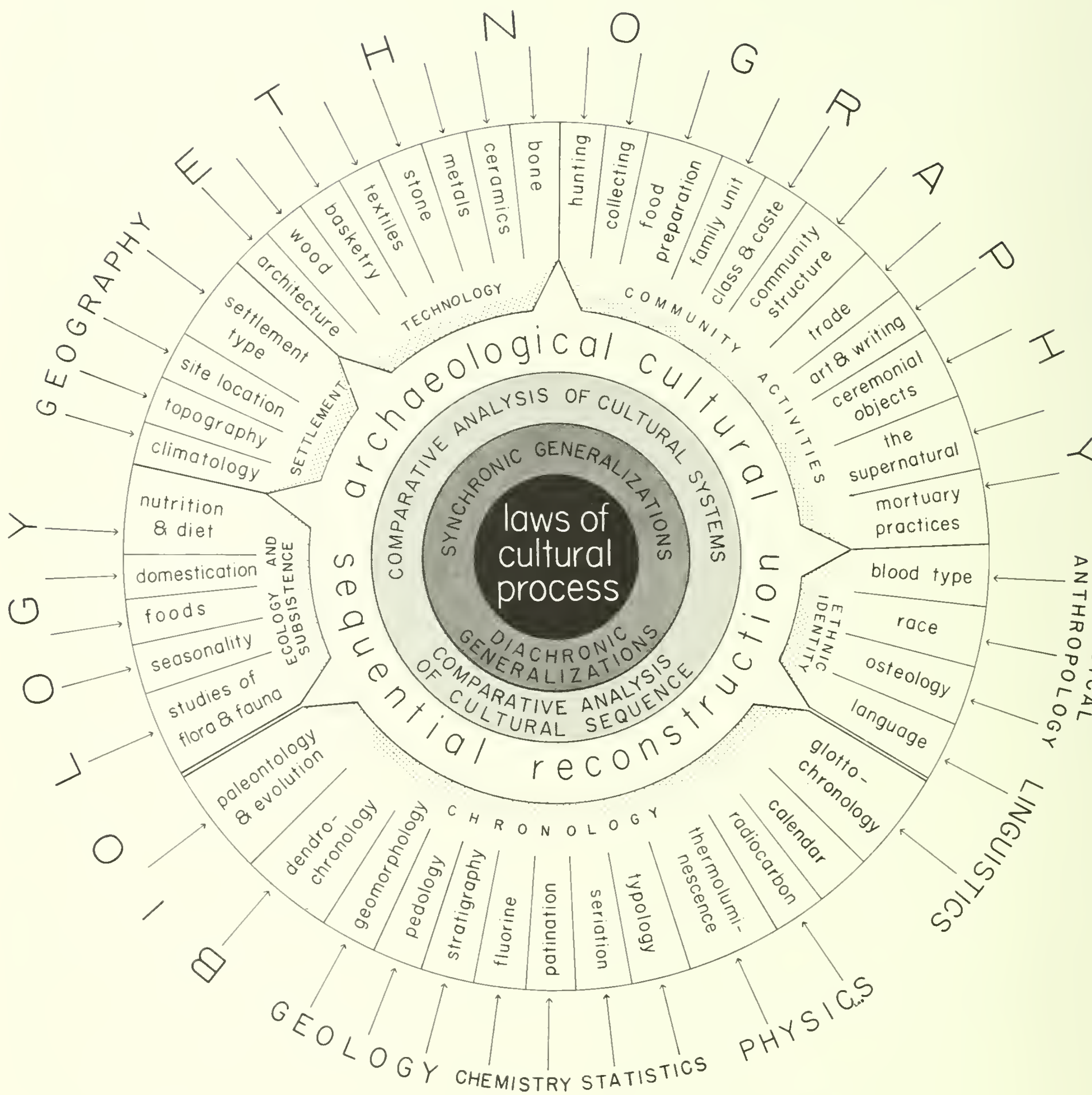

Fig. 2. The interdisciplinary solution of archaeological problems.

of three kinds of excavated materials: remains of food plants and animals found in the various components, feces, and tools connected directly with subsistence.

Owing to the dryness of the valley, fruit pits, fragments of stems and leaves, chewed quids, tiny seeds —literally any object that the ancient inhabitants dropped on the cave floors or laid aside for storage— have been preserved, albeit in a dehydrated state. Together, these normally perishable remains and the discarded bones of food animals constitute what we have referred to as "refuse" or garbage.

Before we could analyze the refuse with a view to reconstructing the sustenance of the early people, it was necessary to identify the species of animals represented and to estimate the minimum amount of edible meat derived from these animals. Remains of both wild and domesticated plants, once they were identified, could also be expressed in terms of the minimum amount of food that they would have supplied. Thus for each zone for which there were preserved foodstuffs, we had estimates of the total amount of food which these remains supplied. We could divide this total among sources of food—meat, wild plants, and cultivated plants—in order to arrive at percentages of the diet derived from each source. A floor-to-floor comparison of these percentages revealed a shifting reliance on the different sources of food with the passage of time. Obviously the range of error in such calculations is rather wide, and such factors as uneven preservation of vegetal foods in earlier levels forced us to make statistical adjustments. Be that as it may, our errors are consistent for each floor through time, and the trends revealed by the estimates are probably valid. These estimates are discussed in detail in Chapter 14.

Over two hundred feces from the sixty floors in which perishable materials survived were available for analysis (see Chapter 13). Of these, more than one hundred are interpreted as being of human origin. Thousands of small particles of food from the feces were separated and identified under the microscope, in an effort to reconstruct the diet for each floor and sequential phase. However, estimates of proportions of the sustenance from different sources based on an analysis of coprolites are subject to peculiar kinds of errors, for finely ground corn in tortillas seemingly leaves no trace, while remains of unground plant food and roughage may be easily found. Nevertheless the identity of many plant and animal foods and changes in their use were revealed by analysis of the human coprolites and served to supplement or corroborate information derived from the more abundant garbage remains.

A study of the tools and features connected with subsistence activities is obviously the least reliable method of estimating subsistence. Here one may assume on the basis of ethnographic data that projectile points indicate hunting; that mortars, pestles, milling stones, and mullers represent plant collecting; or that manos, metates, comales, and molcajetes are used in the preparation of agricultural foods. Obviously tools that we assume were for preparing agricultural products could also be used for wild plants, and vice versa. Further, it is easier to make and then lose a projectile point than it is to do the same with a metate. In spite of these weaknesses, a study of technology permitted us to make rather rough estimates of the proportions of food derived from the several sources, and a floor-to-floor comparison of these estimates did show trends in subsistence.

Although each of the kinds of subsistence data has definite limitations, estimates based on a study of all of them, together with some knowledge of ethnography and characteristics of the skeletal remains, did allow us to make a more acute judgment about subsistence activities. Since the different kinds of subsistence activities and changing trends through time exhibited by artifacts and other materials associated with them are discussed at length in the concluding chapter, I will not go into further detail here. Techniques of preparing food—as reflected by the artifacts, the refuse, the feces, and even the skeletal remains—also changed through time. These techniques are discussed in the final chapter, as well as in the chapters below dealing specifically with animal bones, plants, coprolites, and physical anthropology.

We also attempted to reconstruct the ancient technology and take note of any changes. This is what archaeologists often claim they can do best by making inferences from careful studies of the material culture of living peoples. Quite frankly, neither we nor the majority of Mesoamerican archaeologists have done this kind of reconstruction as thoroughly as we should. We, like most of our colleagues, studied the chipped-stone tools. After examining specimens under a hand lens or microscope and taking note of features characteristically produced by techniques that we tentatively identified, we have been able to turn to ethnographic and modern accounts of flint-knapping and make inferences regarding techniques used by ancient inhabitants of the Tehuacan Valley. Although our conclusions may in the main be valid, it is unfortunate that we were

unable to undertake thorough studies of implements under the microscope and attempt by experiment to reproduce features so identified, as was done in the pioneering studies of Semenov and his colleagues. Such investigations are essential to a more exact reconstruction of flint-knapping techniques and ways of using tools than we now have.

Criticism of the same order could be leveled against our studies of pottery. Although Ing. Arturo Sotomayor was able to make thin sections of sherds and complete petrographic analyses, we did not have sufficient time to sample clay beds in the valley in an effort to find sources of the clays. Although we could easily determine the hardness of the pottery and could make judgments about processes of manufacture and firing, we had no opportunity to undertake experimental and ethnographic studies in support of these observations. Although surface finishes, vessel forms, and decorations are carefully described, there has been little attempt to understand their psychological meanings. Studies of the mineralogy and chemistry of paints and of our few copper specimens is even more superficial.

Analysis and description of objects made of fiber—string, nets, mats, sandals, and textiles—is somewhat better, because these—especially the textiles—underwent careful study and could be viewed in the light of knowledge of similar products made by living peoples or known from other dry archaeological sites. Analysis of these objects would have been more valuable if we had been able consistently to identify the fibers from which they were made. An investigation of comparable industries among living peoples in the area would also have been profitable.

With the aid of a microscope we studied the groundstone tools, and objects of bone, shell, antler, and wood. Here again, for comparative data we often relied on discussions of similar industries in ethnographic accounts. We made no attempt to reconstruct the technologies of stone quarrying, masonry, architecture, sculpture, and other aspects of aboriginal life. Thus our discussion of the total Tehuacan technology to be described in seemingly endless pages in Volumes II, III, V, and VI is far from complete. I hope that future investigators will be able to make great improvements on it.

Our studies of the aboriginal population are also incomplete. Obviously seventy-three burials, often fragmentary, representing nine cultural phases which span nearly 10,000 years are a very inadequate sample of the prehistoric population of the valley and certainly provide little basis for judging population trends. The valuable information derived from physical anthropology concerning age, sex, stature, and pathology is as yet too limited to be useful in a demographic study. Future excavations in the Tehuacan Valley could easily supplement these data.

A second method of deriving an estimate of populations and population trends is to work backward in time from post-Conquest records. Some of the data of Cook, Simpson, and Borah relate to the Tehuacan Valley. As listed and discussed in Chapter 3 below, counts of post-Conquest population of many towns exist, though often in terms of families or tribute payers. These estimates justify a guess that the total population of the valley about A.D. 1514 was between 90,000 and 120,000. Close study of documents relating to the Señorio of Teotitlan del Camino in Conquest and pre-Conquest times would probably allow even more exact estimates. Nevertheless, the post-Conquest population figures provide some basis for judging the accuracy of the site survey and estimate of the total number of occupied settlements of the Venta Salada phase. By dividing the total population at the time of the Conquest by the number of known sites of the Venta Salada phase, we obtain a ratio which we can then apply to settlements represented by occupation floors in excavated sites and by survey sites during each of the preceding phases—Palo Blanco, Santa Maria, Ajalpan, and so on. Thus the trend of population can be worked out for the whole sequence, using the 454 sites found by a survey and the 156 occupations uncovered by excavations.

Data obtained from the site survey and from excavations afford a basis for outlining settlement patterns during each of the sequential phases. Studies of artifacts provided knowledge of the forms characteristic of the several phases. This, in turn, allowed us to place about 350 of the sites recorded by the survey in their proper phases. Next, the survey data for each site was examined for information regarding location with respect to topographic features, size and plan, arrangement of settlement with respect to architectural features, and the relationship of the site to other sites within the same phase. In this manner we gradually came to some understanding of the pattern of settlements characteristic of each phase. Had we been able to excavate a number of examples of the different types of settlement for each phase, our study would be considerably enriched. Even so, it is quite complete and relatively unique for Mexico, particularly in the ceramic phases.

In the preceramic phases the information from the excavated components was even more instructive than the site survey data. Populations of camps could be estimated on the basis of the size of occupied zones and the number of hearths each contained, qualified by data

limiting the period of occupation derived from animal and plant remains and as documented by analysis of feces. Together, these gave us some basis for judging the time of year at which people moved to the site and the length of time they stayed. Estimates of populations could be made by dividing the duration of each occupation in terms of approximate number of days into the estimated total amount of foodstuffs, expressed in liters, represented by the refuse in the zone. On the assumption that a person ate about a liter of food a day, the result should give an indication of the population occupying a certain site at a given time. An analysis of population and settlement pattern will be one of the main concerns of Volume V.

All this information—length of occupation in terms of seasons, density of population, seasonal occupation of camps of the earlier phases—can be viewed in the light of reconstructed subsistence patterns and environment during the earlier preceramic phases and thus used as a basis on which to make postulations regarding the organization of society among the earliest people. Steward and other social anthropologists have established that peoples resident in a harsh desert environment in which there is a low population density, whose subsistence is based upon the food-collecting habits of seasonal nomadism that brings small groups together in seasons of abundance, are usually organized into bands, recognize band territories, and have a weak patriarchal leadership. All evidence bearing on population density, seasonal nomadism, subsistence, settlement pattern, and environment during the El Riego and Coxcatlan phases points to conditions analogous to those described above, and it therefore seems probable that during these phases people were organized into bands, subscribed to rules of band exogamy and territoriality, and were under weak leadership.

Environmental conditions, density of population, settlement pattern, subsistence pattern, and other characteristics found in our later phases—Abejas, Ajalpan, Santa Maria, Palo Blanco, and Venta Salada—have not as yet been correlated with specific types of social organization. However, this represents a worthy avenue of investigation and I shall attempt to pursue it in Volume VI. The social organization of the final phase, Venta Salada, could be better learned by close studies of such sources as codices and *relaciones* in which there are data bearing on the organization of society at the time of the Conquest.

Other archaeological data can aid an attempt to reconstruct the social organization. Burial practices give some hints as to class and caste, as well as the type of family and kinship organization. Figurine types and changes in them may reflect changes in the kinship system. Different kinds of houses and architectural features yield some information about class as well as about political and religious organization. Analysis of artifacts suggests the possible existence of full-time specialists or craftsmen. Discovery of objects brought by trade from other regions offers grounds for forming ideas about commerce. The finding of sites of the Palo Blanco and Venta Salada phases connected with a salt industry unfolds information about special products carried by commerce.

The aspects of society concerned with the supernatural or with religious organization can be inferred on the basis of information derived from a variety of sources, included burials, figurines, types of incense burners or *xantiles*, and types of architectural features and their arrangement. Again the ritual codices, particularly the Borgia Codex, which may be closely connected with the Venta Salada phase, reveal much about ceremonies, gods, and ritualistic and religious aspects of the life of the people.

Such inferences about social aspects of the people known to us only through archaeological phases will be dealt with in future volumes of this series. Since the phases of the Tehuacan sequence will be mentioned repeatedly throughout this and succeeding volumes, brief summaries of the characteristics of each are given below:

Ajuereado. Ended well before 6500 B.C. Traces of cave occupations, probably by small groups of a few families. People were hunters, trappers, and plant collectors. A few chipped stone tools, most of them crudely made from flakes.

El Riego. 6500–5000 B.C. Many wet- and dry-season camps of people who lived by hunting, trapping, and collecting. First hints of plant cultivation. A larger number of types of chipped-stone tools and the first groundstone implements, nets, coiled baskets, twined mats. Ritualistic multiple burials, with suggestions of human sacrifice.

Coxcatlan. 5000–3500 B.C. Fewer sites, occupied over longer periods by larger groups. People were basically plant collectors who also trapped and hunted. Firm evidence of cultivation of a number of plants, including corn, beans, squash, and chili peppers, and indications of experimentation with fruits. Enlarged inventory of chipped- and ground-stone tools; metates begin to replace milling stones; improved techniques of basketmaking and netting.

Abejas. 3500–2300 B.C. Significant change in settlement pattern; some people living, possibly year-round, in pit-house villages along river terraces on the western

flanks of the valley. Agricultural foods now supply over 20 percent of the diet and include new species. First evidence of the domestic dog. New types of chipped- and ground-stone artifacts; split-stitch baskets; possibly cotton thread.

Purron. 2300–1500 B.C. Known only from two cave occupations, this phase is characterized by distinctive, crude, crumbly pottery that is among the earliest found in Mesoamerica. Other artifact types continue in forms represented by the Abejas and Ajalpan assemblages.

Ajalpan. 1500–900 B.C. People have become subsistence farmers living in wattle-and-daub villages on the flood plains. Crops include corn, beans, squash, chili peppers, amaranth, avocados, sapotes, and cotton. Large quantities of chipped- and ground-stone tools; sizable samples of well-made pottery in a limited number of vessel forms. Figurines develop from early, crudely made, solid types, unlike any others in highland Mexico, to later, hollow or solid large figurines resembling early examples from lowland regions (see Vol. III).

Santa Maria. 900–200 B.C. Increased number of components indicates population growth. First structural evidence of true irrigation; people were also farmers of the flood plain and barrancas, growing improved races of corn and many other plants. Villages of wattle-and-daub houses, oriented to a larger village containing ceremonial structures, were located in valley bottoms near Ajalpan, Tehuacan, Tepanco, and at the mouth of the Arroyo Lencho Diego, not far from Tilapa. Well-made white and gray pottery shows resemblances to early pottery of Veracruz and Monte Alban. A varied sample of figurines, including types intrusive from other parts of Mexico, provides inferences of religious and secular organization involving a pantheon and powerful priests and chiefs. Other artifacts include new kinds of stone tools, woven cotton cloth, and possibly twined sandals.

Palo Blanco. 200 B.C.–A.D. 700. Farmers of the valley regularly used irrigation; new domesticates include peanuts, guavas, and turkeys. Numerous settlements, consisting of villages and hamlets oriented toward, or adjacent to, large hill-top centers with elaborate stone pyramids, plazas, ball courts, and other structures were located on many of the hills or mesas between Calipan and Teotitlan del Camino; others were built on hills along the northwestern side of the valley near Zapotitlan. These centers suggest that priests and kings or priest-kings ruled, assisted by a hierarchy of bureaucrats and consultants. Effigy incense burners indicate that worship of some of the gods later recorded in Codex Borgia and other codices may date from this time. Artifacts include finely made tools of obsidian, bark cloth, woven fabrics, fine gray and fine orange pottery.

Venta Salada. A.D. 700–1540. Valley was probably divided into city-states or kingdoms made up of towns and hamlets surrounding urban centers, often fortified, situated in the flanks of the valley in the same locations as present-day towns. Camps, shrines, villages, salt-making sites, quarry sites, and guard-houses and habitations connected with a wide range of irrigation features were spread throughout the region.

Economy was based on irrigation agriculture, commerce, salt-production, processing of cotton, and making various stone implements. Material culture as a whole is a variant of the Mixteca-Puebla style and artifact complex. Social organization was intricate and stratified. Development of a hieroglyphic system made possible the documentation of an elaborate religion, a complicated calendrical system, and much ceremonialism.

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CHAPTER 2

Field and Laboratory Techniques

Richard S. MacNeish

The solution of the more general problems discussed in the preceding chapter depended basically upon information derived from field work and field laboratory. Although the techniques we used in the field are well known to most archaeologists, a brief description of them here may be useful to future workers. Obviously a number of rather practical objectives and problems aided and at times determined the formulation of field and laboratory techniques.

Although the discovery of Coxcatlan Cave with its early corn had brought us to Tehuacan, the initial field problems were, first, to define the area in which we would work and then to discover the sites within it whose excavation would give the most complete regional cultural sequence. Obviously the region had to be dry if we were to find the remains of perishable agricultural products grown in early times, but the region also had to be a cultural unit. Study of maps published by the Papaloapan Commission provided the environmental data that we needed. At first we defined the region in terms of an annual rainfall of less than 800 mm. and the consequent xerophitic vegetation. We also felt that the region should be in some measure a topographic unit. With these three factors in mind, we turned to the maps again and set the rough boundaries of the region in which we would work. At this time we made note of problem areas within the region which shared only one or two of the three characteristics. Then Fred Peterson and I took to the field to test our hypothetical environmentally defined region and see if the archaeological material correlated with it.

We commenced by working around the Tehuacan Valley, gradually eliminating surrounding areas that either contained cultural materials of a different type or which lacked the characteristic desert features. First, we worked as far west as the Pan-American Highway, at Huajuapan de Leon in Oaxaca. Next we drove into the high sierras to the northeast of the town of Tehuacan, and then made a foray beyond Teotitlan del Camino in the southeastern end of the valley. Finally we worked northwestward until we were just south of the city of Puebla. By this process, we gradually developed a general concept of the cultural and environmental dimensions of the region with which we were concerned. This was finally defined as the Tehuacan Valley from Tlacotepec de Diaz, on the northwest, to Tecomavaca on the southeast, a distance of about 80 miles. The northeastern limit of our area lay in the rain shadow of the Sierra Madre de Oaxaca on the southeastern flank of the Sierra de Zongolica. The southwestern edge was formed by the foothills of the Mixteca Alta on the southwestern side of the Tehuacan Valley. To the valley proper we added the nichelike extension on the west formed by the Zapotitlan Valley as far as Acatepec.

Although we later modified the limits of the area to some extent, we found that generally the region lay north of Tecomavaca, south of which point the Postclassic pottery was of a different kind and the character of the desert vegetation changed, though the rainfall and topography did not. Northward, Tlacotepec appeared to mark a boundary beyond which new kinds of Classic and Formative pottery began to appear, although the valley's distinctive Postclassic pottery and the area of low rainfall extend about as far north as Tecamachalco. Moreover, the vegetation noticeably changed, and the valley was interrupted by a series of low hills. The east and west sides of the valley were

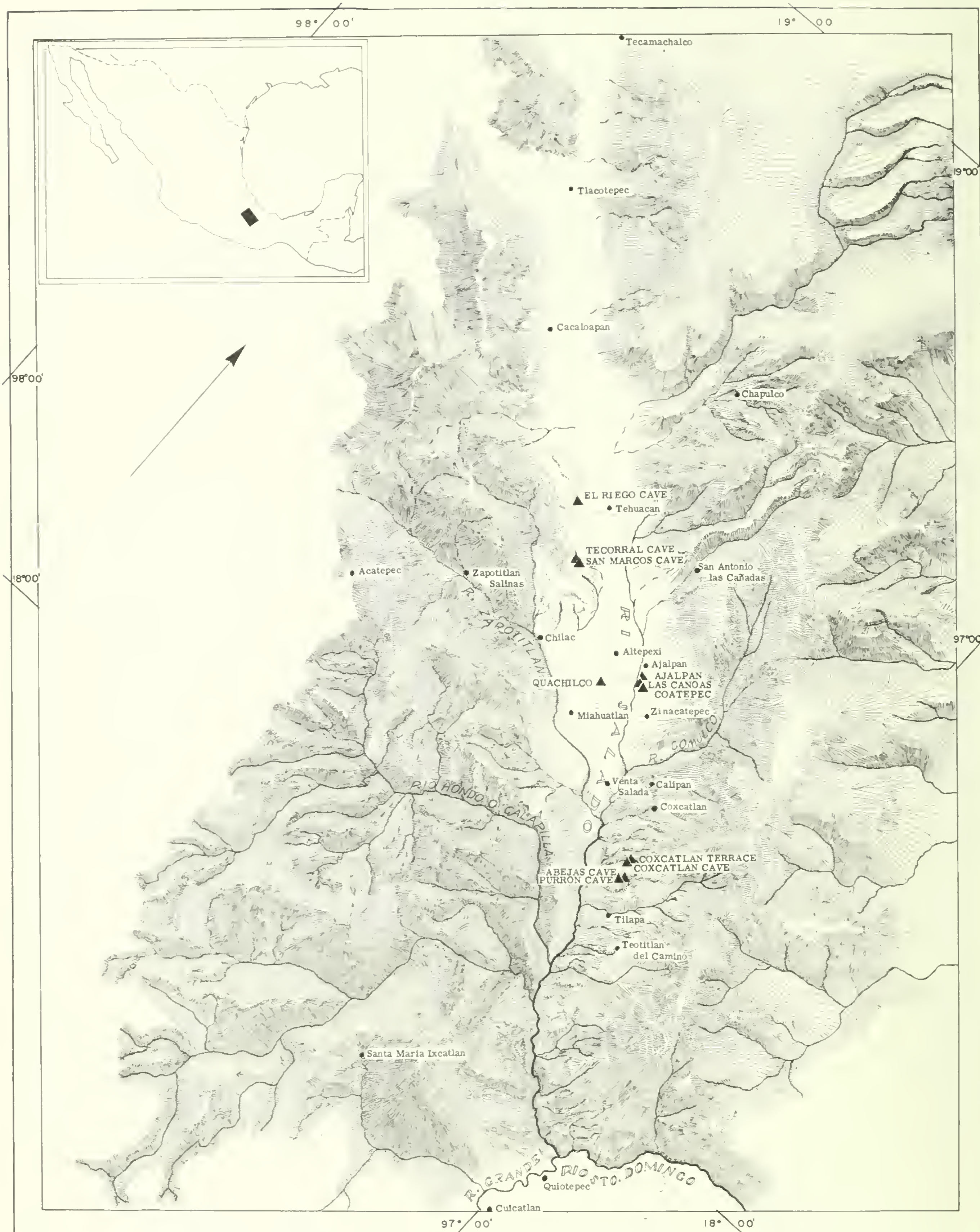

Fig. 3. The Tehuacan Valley. Triangles indicate archaeological sites.

easy to define by the increased rainfall, wetter oak and pine montane vegetation, and mountain-side topography. To the west of Acatepec even the Classic pottery was different. Within the boundaries we set was a cultural subarea or region in the "Kroeberean" sense of the word, and this is where it seemed advisable to concentrate our intensive reconnaissance efforts.

Having defined our region in a general way, the next task was to find the most productive sites in it. We wanted to excavate sites with deep, well-preserved, stratified deposits and sites that contained materials typical of each part of the sequence. We wanted to find the places in our region where the ancient inhabitants preferred to live. Using this knowledge of settlement or community pattern, we hoped to dig the sites which would give the maximum information with the minimum of time and effort.

Ideally, this aim could have been achieved by choosing a small part of the region, surveying it intensively, analyzing the materials from the survey to establish a sequence, and then evolving hypotheses about the settlement pattern. These hypotheses could then be tested and modified by reconnaissance in the various subregions until the entire region was covered. Analysis of all the surveyed materials would then be the basis for choosing the best sites for excavation.

Needless to say, we did not adhere strictly to this ideal pattern. First of all, from the preliminary survey I made in 1960 I had roughly formulated a hypothesis regarding the kinds of caves that would have stratified deposits. Second, Peterson and I had sufficient knowledge of Mexican archaeological chronology to enable us to set up hypotheses about the sequence of artifacts that should be found in the Tehuacan Valley. We did, however, survey rather intensively around El Riego, just north of Tehuacan, and we did test my hypothesis about characteristic features of stratified sites. We also undertook some digs to test our theories regarding the sequence of the artifacts. As a result of these efforts, we postulated that caves containing stratified deposits would be characterized by a wide mouth, a depth from front to back of three or more meters, a dry ashy floor, vertical walls indicating a workable deposit of refuse, and would exhibit on the talus a wide variety of sherds and chipped-stone artifacts. Also, we discovered that hill tops were capped by large ruins with pottery like that of the Classic period of Monte Alban and that on the sides of the valley were large ruins with Post-classic Mixteca-Puebla pottery.

With these hypotheses in mind, we settled into our region, planning on a long-sustained reconnaissance. However, the survey was so productive and materials came so fast that it was impossible to keep up with the analysis of them. Further testing of hypotheses about settlement patterns was more subconscious than conscious. Peterson continued the archaeological survey for eighteen consecutive months and eventually covered the region thoroughly. Our sequence in the meantime was established, not on the basis of analysis or survey, but on the basis of the findings of tests at several stratified sites. The study of settlement patterns was accomplished only in 1964, after the materials from the survey had been totally classified. This final study, undertaken by James E. Neeley, was, from many points of view, more successful than our ideal plan, for by this time the sequence had been firmly established, and we had rather definite ideas about the settlement pattern of each phase. Therefore, Neeley had a good opportunity not only to check our hypotheses regarding settlement patterns in toto, but also to check on features we might have missed in the early part of the survey.

We decided at the outset that we would record the survey as simply as possible so that our relatively untrained assistants would have little trouble cataloguing objects found. Each site was given a number, preceded by an abbreviation keyed to its character. The letter "T" for Tehuacan project always preceded a small letter, "r," "c," or "s," which meant, respectively, a ruin or site with architectural features, a cave, or an open site without architectural features. Thus "Tc 9," for example, was a cave site and the ninth site found by the Tehuacan project.

When a site was found, it was given its appropriate designation according to this system, and this site number was written at the appropriate spot on one of the detailed contour maps of the Papaloapan Commission. We then entered on a data sheet essential information about the site, such as location, ownership, municipio, topography, architectural features, dimensions, and so on. The sheet also had space for a sketch map of the site. Peterson made rough maps of some of the sites, but later Neeley supplemented these with maps made with a Brunton compass and tape.

Artifacts found on a site were placed in cloth sacks. When a surface collection was completed, we identified the bags by writing the number of the site in India ink on each of two parts of a perforated manila tag. We then placed one part of the tag inside the bag with the specimens and tied the other part outside at the neck. Thus there was little chance that site numbers could be lost before the artifacts were washed and the site designation written on each specimen. In 1964 all the artifacts from each site were classified, and the number of artifacts of each type was recorded on a sheet for

each site which we clipped to the original survey sheet. In his resurvey, Neeley made some attempt to associate various types of artifacts with various architectural features; in special problem cases, the exact location of particular types were noted. Generally speaking, however, we did not use random-sample techniques, and all visible artifacts and rim sherds were collected. Nor did we employ dog-leash survey techniques, although the results in cactus forest and among rocky crags might have been interesting.

The greatest weakness of our survey methods was lack of time, not the lack of statistical techniques. The ideal approach, as I have said, would have been to survey a small segment of the valley, analyze the results, and then continue surveying by sub-region until the valley was fully covered. Analysis of the total results of the survey would have determined a tentative sequence and typology, and on the basis of this information we would have selected our sites for excavation. However, at the beginning of the project we were not sure that we could support so long a survey period. Furthermore, our initial testing seemed to be giving more reliable sequential data for choosing stratified sites than could a seriation study of surface collections.

Regardless of shortcomings, we did discover 454 sites within the limits of our region. On the basis of about 100,000 sherds and 5,000 artifacts, we were able to place 350 of the sites in their proper cultural phase. This gave us considerable information about changes in settlement pattern. Furthermore, we tested thirty-nine sites with potential stratigraphy and found that about a dozen of these were good enough to warrant full-scale excavations.

The principle basic to the preliminary tests was also basic to our digging technique: that is, to strip off actual strata exposed and identified on a cleaned vertical profile or profiles that clearly showed a cross-section of both cultural and natural stratigraphy. By digging from a vertical profile, where the stratigraphy could be seen clearly, we could move forward carefully and take off each stratum with relative ease and the greatest possible exactness.

In the test, then, as well as in the major excavation, the first task was to expose a profile. Usually we started a trench one-meter wide and from three to six meters long that cut across what appeared to be the deepest stratified deposits. In caves, we often laid out the trench to cut across the middle of the shelter from the edge of the talus to the inner wall. In open sites, we laid out the test to get greatest return according to local conditions.

After we staked out a one-meter square and, by horizontal stripping deepened it until we reached the bottom of the deposit, we could move into one wall of the square and then the opposite one, stripping identified strata for a distance of one meter from the vertical profile. Later, as conditions demanded, we could extend this three-meter trench by the same method until we reached the end of the deposit. Once the trench was finished, we studied carefully the artifacts from each stratum, and perishable materials recovered, and the strata themselves to decide whether the cave or site was worth a major effort. Of the thirty-nine sites tested, only eleven—Tc 35, Tc 50, Ts 51, Ts 204, Tr 218, Tc 254, Tc 255, Tc 272, Ts 367, Ts 368, and Tc 307—proved to have deep, well-preserved deposits or to contain materials representing large segments of the regional sequence.

In the major digging of these sites, procedure and direction of vertical slicing or stripping varied slightly according to local circumstances, but the general methods of excavation were roughly the same. First, we studied the vertical profile exposed by our test in order to distinguish the strata so that we might give each a numerical or alphabetical designation; next we drew and photographed the profile; then we emphasized the limits of each stratum by incising dividing lines and driving into the outlined stratum a spike carrying a tag with the designation number or letter.

Our next step was to lay out a one-meter grid over the area to be excavated, numbering stakes according to a relatively simple system of coordinates. A stake designated "0–0" was placed near the center of the area that we planned to excavate to mark the intersection of the north-south base line and the east-west base line. At one-meter intervals lines paralleling each base line were designated N1, N2, N3, and so on; S1, S2, S3, and so on; E1, E2, E3, and so on; W1, W2, W3, and so on. Stakes set at the intersections bore the designation of the intersecting coordinates with the N–S ordinate always first—thus the stake at the crossing of North 1 and East 1 was N1E1; that at North 4 and West 7 was N4W7. Each square carried the number of the stake in its southeast corner.

With the squares adjacent to the exploratory trench staked out and numbered, the profile studied, and the zones within it given a letter or number, we were ready to move into the vertical face or faces of the trench. We usually dug alternate squares next to the test trench, using three-man teams in each square. The first man, the skilled digger, stood in the test trench and stripped off the top stratum in the square in front of him. His tools varied with the composition of the stratum and the kinds of materials being uncovered. Ordinarily, he

Fig. 4*a*. The application of the alternate-square technique: the grid is laid out and excavation begun at Ajalpan.

Fig. 4*b*. A large pit results from excavating the isolated squares in Coxcatlan Cave.

Fig. 4c. The zones have been isolated and identified, so that the strata can be followed without difficulty in Abejas Cave.

Fig. 4*d*. Even in this deep pit at Coatepec the excavation is under perfect control through tracing of zones and location of corner posts.

used a trowel, but on occasions he might use a small pick, a spoon, an ice pick, a grapefruit knife, a paint brush, a whisk-broom, or even a teasing needle. He never used a shovel! The second man was the clean-up and bucket man. He sometimes cleaned up the excavated dirt with a shovel, but most of the time he used a dust pan or flour scoop, putting the loose dirt in a bucket so it could be carried to a quarter-inch mesh screen, where the screen man sifted it and collected any artifacts or bits of plant material missed by the other two workers. Using this system, we carefully removed each stratum in the alternate squares to a convenient depth of about two meters. In like manner we removed the isolated squares, standing out like buttresses so that the strata could be seen on all three sides. In this way we were able to obtain both north-south and east-west profiles and to continue the system indefinitely. If we were required to make special excavations, such as those for burial pits, we might be forced to depart from this procedure, but such occasions were relatively rare.

Perhaps even more important than this well-controlled technique of excavation and its resultant finds of artifacts in context was the recording of the progress of both excavations and findings. First and foremost, our field notes, maps, and so on were the only record of the archaeological evidence we were so carefully destroying with our digging. Secondly, we believed that the best "policy decisions" concerning our excavation techniques should be based upon analysis of the materials from the excavation. Thus, ideally, analysis and excavation should go hand in hand, and our field records should not only describe precisely what, where, when, and how the material had been exhumed, but should do so in such a manner as to assist and speed the field analysis. Obviously, with a number of scientists describing the excavation, a uniform system had to be established, otherwise the individuality of notetakers would have made the task of the laboratory analyzers much more difficult and slower. We therefore adhered to the system described below, not because we felt this or any system was perfect, but because we wanted both the digging and the analysis to be co-operative and interstimulating.

We usually made a contour map of the area to be excavated shortly after the initial staking and numbering of the grid. At this stage we also took photographs of the site before digging began. We kept a daily diary on looseleaf sheets, describing the excavation, the numbering of the grid, the strategy at the beginning of excavations, the names of workers, and other details. As soon as we began excavations, we started filling out loose-leaf printed forms we called "square descriptions." As each level or zone of each square was excavated, a sheet was filled out recording site number, square number, date, names of workers, level, zone, depths, and comments about artifacts uncovered and the characteristics of the zone. As we completed the excavation of each level of each square, we prepared a two-part tag, giving the site number, designations of square, level, and zone, the date, name of worker, and other information. One part of the label went into the bag with the specimens and the other part was tied outside. We also made an attempt to separate, wrap in foil if necessary, and individually tag various kinds of specimens—projectile points, corn cobs, scraps of textiles, sherds, and so forth—that went into the labeled bags. The person in charge meanwhile made notes in the daily diary, indicating possible correlation with zones in adjoining squares, listing artifacts found, and recording contextual data and the drawings and photographs that had been made. There was a special sheet in the loose-leaf notebooks for a photographic record. Floor plans, drawn on loose-leaf sheets of graph paper, were also included.

When we uncovered burials or features such as pits, fireplaces, architectural structures, or concentrations of artifacts, we described them on Burial Record or Archaeological Feature Record forms. These forms were supplemented by further descriptions in the daily diary notes, by drawings, and by photographs.

Among the most important records we kept were profile drawings. Profiles were drawn at a scale of 1/100 or 1/50 on millimeter graph paper, one sheet for each line on the grid. We also attempted to photograph as many vertical profiles as possible.

I hope that the following pages, and the other volumes of this series, will demonstrate that our records were carefully kept. The excavation supervisors and their aides were as busy as the diggers. One difficulty with our field technique was that it demanded more student assistants than were available to us to help keep records and thus leave the excavation supervisor free to deal with more important tactical and analytic problems. Because we did not have enough student assistants, the daily diary and square descriptions were occasionally a little brief.

Sound archaeological techniques and as complete recording of excavations as possible are basic to any archaeological study, but it is equally important that the specimens uncovered be recorded carefully in the laboratory and prepared for study and analysis. Thus, ideally, field laboratory work should keep pace with field excavations so that the former may supplement

and at times guide the latter. One valid criticism of our execution is that we should have had a crew of twelve to fifteen workers to prepare the artifacts and carry out the cataloguing, so that analyses could have paralleled excavations a little more closely.

One of the prime duties of the field laboratory is to catalogue the material found. This work was done for us by a three-man team, two of whom did the washing, repairing, and numbering while the third entered the record in the loose-leaf catalogue. We wrote numbers directly on specimens or on a small tag that was attached to the specimen or its container or foil wrapping. If the artifact came from a surface collection, it was labeled only by the site number. A separate loose-leaf sheet was made out for each site, listing the various types or kinds of artifact uncovered there. Usually this sheet was clipped to the appropriate survey sheet and filed together awaiting further study.

Cataloguing of artifacts from an excavated site was a little more complex. In order to record all essential facts we employed a fractional designation with the site number in the position of the numerator and the denominator consisting of three parts, representing the square, the level or zone, and the kind of material. This number was written on the specimen or an attached label and also on a loose-leaf catalogue sheet for each site.

After the specimens were numbered, there came the question of storage. To keep the catalogued specimens easily accessible, each category of material was stored in a box properly labeled with inclusive catalogue numbers, the kind of material, and the site, zone, and location within the zone from which the specimens came. These boxes were stored in sections of shelves reserved for the various kinds of artifact. Thus all the boxes containing projectile points occupied one cubicle on our shelves, the boxes of bifaces another, and the boxes of unifaces or bones, beans, corn, and so on, still others. Throughout our analysis the boxes were shifted around considerably. Initially we studied stone and other nonceramic artifacts for chronology, and visiting scientists studied their respective kinds of materials. When these studies were completed, the boxes of material involved were put in dead storage and other boxes replaced them in the various cubicles. Still later, when we analyzed sites by floors, the cubicles were filled with all the materials from a specific floor of a specific site. Later, boxes of ceramics replaced these. After we had completed our analysis, we transferred the collection, in boxes classified by type and kind of specimen, to the Museo Nacional de Antropología in Mexico City.

By employing the laboratory and field techniques described above, we found it possible to attack the problems of chronology and the interpretation of cultural contexts through time in the Tehuacan Valley. Of course, the methods employed in these studies, discussed in the previous chapter, allowed us to consider even wider cultural problems. From any standpoint, however, whatever success we may have had in solving such problems we owed to our basic field and laboratory techniques. The field techniques gave us data which were scientifically reliable and our laboratory techniques organized the data in such a manner that they could be brought to bear relatively easily upon the larger problems.

CHAPTER 3

The Region and Its People

Douglas S. Byers

TEHUACAN, one of the important cities of the state of Puebla, lies in south-central Mexico, close to the border between that state and the state of Oaxaca. Its name, variously interpreted to mean "Place of the Gods" or "Place of Stones" (Barrera 1946), has been given to a valley that occupies part of the northwestern portion of a great down-faulted trough or graben, usually known as La Cañada Oaxaquena-Poblana, the Oaxaca-Puebla Trough. In common with that of other geological structures of this part of Middle America, the trend of this great structural valley is in general north-northwest to south-southeast.

The northeastern wall of the valley is formed by the Sierra Madre de Oaxaca, a series of connected ranges for which there is a multitude of names. It is a southward extension of structures of faulted and folded marine clastics and metamorphics, sometimes with inclusions of crystalline rocks, that are characteristic of the Sierra Madre Oriental. The Sierra Madre de Oaxaca was formerly considered to be a part of the Sierra Madre Oriental, but in recent years it has been distinguished from it for several reasons. For one, the Sierra Madre Oriental forms the eastern rampart of the Central Plateau, while the Sierra Madre de Oaxaca forms the eastern rampart of a series of valleys and deeply dissected terrain (Tamayo 1962, I: 413). Furthermore, the distinction between the Sierra Madre Oriental and the Sierra Madre de Oaxaca corresponds with the crossing of this structural complex by the Clarion Fracture Zone and Neovolcanic Axis (Maldonado-Koerdell 1964). The latter two features mark the southern limit of the Mesa Central (West 1964). The great cone of Citlaltepetl, or the Peak of Orizaba—at 5750 meters, the highest mountain south of the Mount Saint Elias Range in Alaska—is the principal local landmark of the Axis, but many more, although lesser, evidences of vulcanism and of igneous extrusives are to be found in central Puebla and adjacent Veracruz.

An easy passage from the Tehuacan Valley through the sierra is to be found at Puerto del Aire, where the highway to Veracruz, about 145 kilometers away as the crow flies, crosses to descend by a series of hair-raising switchbacks into the Barranca de Acultzingo and the valley of Rio Blanco. Other crossings, many passable only on foot or by burro, are to be found to the southeast of the city of Tehuacan. The principal modern route, passable by jeep or truck, is from Teotitlan del Camino by way of Huautla. A network of roads and trails connecting the highland towns and hamlets may well preserve the pre-Columbian highway net.[1]

The Sierra de Zongolica—a part of the Sierra Madre de Oaxaca—forms the northern and eastern rampart of the Tehuacan Valley. Confusion surrounds the naming of mountain ranges, for Tamayo shows the Sierra de Zongolica curving to the eastward, while the Sierra de Tlacotepec joins with the Sierra de Huautla to form the northeastern side of the Tehuacan Valley (Tamayo 1962, I: map, facing p. 300). Jean Brunet (Chapter 5)

[1] For a study of the geology of the Tehuacan Valley see Chapter 5 below.

Excellent treatments of the geology and natural history of Middle America by Maldonado-Koerdell, West, Tamayo and West, Collier, Vivo Escoto, and Stevens are to be found in the *Handbook of Middle American Indians*, Volume I (University of Texas Press, 1964). As it is, complexities of the natural setting of the Tehuacan Valley constitute so small a detail that treatment in the *Handbook* could not be adequate for the purposes of the Tehuacan project. That volume should, by all means, be consulted in order to place in proper perspective much of that which follows.

calls these ranges Sierra de Acultzingo, Sierra de Zongolica, and Sierra Mazateca. We shall refer to the range bounding the valley on the northeast as the Sierra de Zongolica, the name used in the Annual Reports of the Tehuacan Project (MacNeish 1961*a*, 1962). Above the southeastern end of the valley the Sierra Mazateca reaches an elevation of 2600 meters or more. Together, these mountains catch much of the moisture from winds blowing off the Gulf of Mexico, and their summits are clothed in cloud forest.

The southern and western sides of the valley are formed by the Sierra de Zapotitlan and other ranges, which are outliers of the heavily dissected northern slope of the Mesa del Sur, collectively known as the Mixteca Alta or Sierra de Mixteca (West 1964: 63). These mountains are not so high as the Sierra Madre de Oaxaca, and they do not receive as much moisture. It is likely that before they were denuded by cropping, burning, or other activities, they supported a forest of oak and pine, such as is now found in the Mixteca Alta. Passages through this highland zone follow either river valleys or mountain ridges. The Pacific Ocean lies more than 240 kilometers from Tehuacan, across these mountains.

At its northwestern end, the Oaxaca-Puebla Trough seems to hang like a ramp from the southern lip of the Mesa Central. It is a broad, high valley, with rather low walls. Indeed, West (1964) refers to it as the Plain of Tehuacan. Through it there is easy access from Tehuacan to the southeastern side of the Puebla Basin, Tlaxcala, and the Valley of Mexico. The ancient state, or Señorio, of Tlaxcala with its populous cities and religious centers occupied the largest part of the basin and, in fact, all the modern state of Tlaxcala and portions of Puebla and Veracruz as well. Between it and the Tehuacan Valley lay the ancient province of Tepeacac.

The modern highway to Tehuacan leaves the Puebla Basin near Tepeaca (el. 2243 m.). This remnant of ancient Tepeacac, once occupied by some 35,000 people, is now a town of 5,172 souls. Entrance to the northwestern part of the Puebla-Oaxaca Trough is by a rolling upland, sloping gently toward the southeast. Turning southward from Tecamachalco (el. 2045 m.)—the ancient Tepemaxalco—the road crosses a barranca and climbs toward Tlacotepec, for the drainage of this part of the trough is away from Tehuacan. From near Tlacotepec (el. 1977 m.) the drainage is southward. "Drainage" is perhaps not the correct word to use, for this part of the trough is a broad, high, arid valley in which water is scarce. Many plantations of agave cover the otherwise barren hills, and here, as in other districts where water is scarce, pulque, prepared from juice of the agave, is said often to be used in place of drinking water. Southeastward from Tlacotepec the valley floor drops gradually but steadily. Water from the Rio Atoyac Poblano, impounded by the Manuel Avila Camacho Dam to form the Valsequillo Reservoir south of Puebla, irrigates the Tecamachalco Valley; that which enters the trough south of San Gabriel Tetzoyocan is used in the Tehuacan Valley. Under irrigation these high valleys yield good crops of wheat, alfalfa, and other produce.

Just northwest of Tehuacan a spur of the Sierra Madre de Oaxaca extends westward into the valley, and an extensive travertine terrace, known as the Cerro de la Mesa, juts eastward, narrowing the valley floor. That part of the valley with which we are chiefly concerned lies to the southeast of the narrowing.

The trend of the Tehuacan Valley is a source of annoyance to cartographers, for it conforms to the orientation of bordering geologic structures—approximately from northwest to southeast—and does not fall neatly into a page oriented to parallels. The limits of the valley can be set roughly between 19°00′ and 17°30′ N. Lat., and between 97°00′ and 98°00′ W. Long. It occupies more than half of the northern part of the Puebla-Oaxaca Trough, the drainage of which is effected by the system of the Rio Salado, flowing southeastward from southern Puebla and northern Oaxaca. The southern part of the trough is drained by the system of the Rio Grande or Tomellin, flowing northward from Oaxaca. Joining near Quiotepec, the two form the Rio Santo Domingo, which cuts through the Sierra Madre de Oaxaca in an easterly direction and eventually becomes the Rio Papaloapan at Papaloapan. Although these streams and some of their principal tributaries carry water throughout the year, their many lesser tributaries, ephemeral or at best intermittent, carry surface flow only during the rainy season.

The ultimate sources of the Rio Salado are shown on the Puebla Sheet (19°00′–97°30′) of the Map of the Republic of Mexico to be on the western flanks of Citlaltepetl (the Peak of Orizaba). However, detailed maps of the Papaloapan Commission (sheets 4, 11, and 19) show no through-flowing perennial stream from this source, and a traverse of the valley from San Lorenzo to the highway between Tehuacan and Chapulco failed to disclose either a stream or a streambed in 1963. It must therefore be assumed that if such a stream ever existed, its waters have long-since been diverted and its bed graded over. The Rio Salado thus finds its effective head in the Rio Tehuacan. One branch of this stream which flows from deeply incised canyons that

Fig. 5. San Antonio Las Cañadas. The church and most houses are along the barranca; a few modern houses are on terraces on the hillside.

drain the Sierra de San Felipe de las Vaderas joins a longer branch that rises just below the crest of the divide little more than five kilometers south of Acultzingo. The Rio Tehuacan finds its way west of the feet of Cerro Colorado de Tehuacan to debouch into the valley near San Diego Chalma. This small river, which becomes the Rio Salado, is joined by a number of rather short, steep tributaries rising in the Sierra Madre de Oaxaca to the northeast, and by fewer but larger and longer affluents that drain the deeply dissected Mixtcea Alta to the southwest.

First of the eastern tributaries is the Barranca de San Antonio which finds its head not far from the head of the Rio Tehuacan but flows on the eastern side of Cerro Colorado de Tehuacan. It follows a rather deep, narrow valley bordered by narrow shelves of what might, out of courtesy, be called flood plains. Their width varies from a few meters to as much as ten or twenty. Almost every available bit of this shelf is planted in native trees, including the local avoeado and others, inports such as coffee and a few citrus trees, flowers such as poinsettias for the valley markets, and other crops. A number of settlements line its course, ehief among them being San Antonio las Cañadas. Its broad fan, now intensively cultivated, supports a eheckerboard of erop land from which there is an important cutting of sugar cane. Up this barranca runs the road to Santa Catarina and San Bartolome Lagunas, and ultimately to the high country, to cross it to the low country of Veracruz.

To the southcast of the Barranca de San Antonio is a mountainous area cut by deep narrow canyons that are drained by the Rio Comulco. Its headwaters lie in steep canyons where there is no opportunity for villages or crop land. Several short, very steep tributaries enter from the flanks of Cerro Paredones. It joins the Salado west of Calipan.

Barranea de los Mangos enters the valley near Calipan. It has its source near the very spine of the Sierra, beyond the hamlet of Tecoltepec. Extensive

Fig. 6. Cactus and thorn scrub near mouth of Arroyo Lencho Diego. The candelabra-like "cardon" *(Lemaireocereus weberi)* is in fruit; the angularly branching form is *Escontria chiotilla;* the smaller form with rounded pads is prickly pear (*Opuntia* sp.)

stands of sugar cane and the fact that a sugar mill was built there give evidence of the water that can be taken from it. This cannot with safety be judged for water is now brought from great distances down the valley, and some that is used below Calipan is said to have come from near San Sebastian Zinacatepec. The section dealing with irrigation, to appear in a later volume, will go more fully into this aspect of the present-day culture of the valley.

Coxcatlan stands at the mouth of the Barranca de Soyolapa, which is the source of water for domestic use and irrigation of the groves and gardens in the town. Above the town, terraces, plazas, and pyramids climbing the spur on the south side of the barranca mark the site of the ceremonial center of an ancient Coxcatlan. It is said by some in Coxcatlan that "the ancients" first brought water to the town from the barranca, but whether it was brought by those who remodeled the mountain spur would be difficult to say.

The Barranca de Aterango, a shorter and steeper channel, joins the Barranca de Soyolapa about two kilometers below Coxcatlan. South of this is a series of arroyos, some shorter and some longer, that drain the western slopes of Cerro Ellotzihuatl and Cerro Chichiltepec. Largest of these is the Arroyo Coxcatlan, on whose unnamed southern fork lie Coxcatlan Cave and Coxcatlan Terrace, beneath the northwest face of Cerro Agujereado.

The next large arroyo is Arroyo Lencho Diego, on whose western side are Purron and Abejas caves. This arroyo, which rises from the southern and southeastern flanks of Cerro Chichiltepec, must carry a sizable volume of water during the rains. Remains of an ancient dam for the impoundment and diversion of irrigation water can be found among the thorny scrub near its lower end.

Other tributaries from the east are the rios de Tilapa, Teotitlan, and San Martin, all of which rise on the western slopes of the sierra and bring abundant water during a large part of the year.

In order to say authoritatively just which of the above-named arroyos and barrancas would flow into the valley as living streams had it not been for the interference of man, it would be necessary to examine each one for evidence of such interference. Certainly many carry an underground flow of considerable volume. The people of the barrancas employ an ingenious method of diverting this flow without the use of dams, which can be washed away or silted up. They first dig a ditch diagonally across the channel at a point where there is an opportunity to trap the underflow. The upstream end of such ditches may reach a depth of two meters or more. Filled with stones, coarse gravel, and sand from the river bed, the ditch then serves simultaneously as a diversion work and filter, from the lower end of which a stream of clear water flows into the aqueduct that carries it to town, orchard, and garden plot. Such diversion works are said to be immune from damage by all but the most severely eroding floods.

The western tributaries of the Salado are bigger and very much longer than those on the eastern side. Nearest to Tehuacan is the Rio Zapotitlan, which enters the valley near the hamlet of Xaco, just west of San Gabriel Chilac. It is immediately joined by the Arroyo de Atexcala, an ephemeral stream that drains an extensive valley just beyond the range of hills that fronts on Tehuacan and there forms the western wall of the valley. Flow in the Zapotitlan is not great, for its drainage lies almost entirely within the most arid part of the area with which we are concerned. After it reaches the valley, its course almost parallels that of the Salado until it reaches Axusco, where it turns eastward to join the Salado near Tlachica.

Next, to the southeastward, is the Rio Hondo, or Calapilla. Its source is in the Mixteca Alta from which it flows first in a generally northerly direction, and then makes a great bend, first to the northeast and east, and then to the southeast, ultimately joining the Salado below Ignacio Mejia, about ten kilometers south-southwest of Teotitlan del Camino. Its course and those of its feeder streams follow deep, narrow valleys with sides that verge on the precipitous and offer scant opportunity for farming.

Next to the Hondo, and inside the curve of its course, is the Rio Xiquila. This rises near Navitas and Coixtlahuaca, in Oaxaca, and also flows northward, eastward, and southeastward to join the Salado about three kilometers below its junction with the Hondo. Like the Hondo, it flows through narrow, deep valleys. Although it offers little opportunity for farming, its waters fed an ancient aqueduct that is described in the discussion of irrigation that will appear in a subsequent volume.

Although the valleys of these two streams do not now support a heavy population, they and the Rio San Pedro, a tributary of the Rio Grande, give access to the country of the Mixtecs, with which cultural connections appear to have been at times quite close.

The principal modern settlement in the valley is Tehuacan, a busy, modern city of 31,734 inhabitants (1960 census, Tamayo 1962: III, 417). It lies at an elevation of 1676 meters and is appreciably cooler and fresher than the towns below. Ruins of Old Tehuacan are scattered along the east bank of the river, over two kilometers away, for a distance of two or three kilometers. The old town, abandoned in the late sixteenth and early seventeenth centuries, had been occupied since early Postclassic times.

Tehuacan is both the distribution point for the surrounding area and the assembly point for agricultural produce and manufactured goods. The latter include cordage, baskets, and palm-leaf hats, some of which are brought from Santa Maria Ixcatlan (Cook 1958). Bottling plants, the principal industry of Tehuacan, use the flow from several springs to supply much of the soft drinks and bottled water sold in Mexico.

Flocks of sheep and goats have overgrazed the surrounding country and contributed greatly to forces eroding the flanks and floor of the valley. The annual kill is said to produce approximately 125,000 carcasses. Many small producers together supply a great quantity of agricultural produce, from flowers and vegetables to grains, including corn, wheat, and barley. The valley is among the grain-producing centers of Mexico (Tamayo 1962: IV, 296). Smith (1965*a*), being based on data gathered during the summer, does not reflect agricultural activities of the winter season when wheat and barley are grown. Much of the small grain is consumed locally, but some is shipped out. Several alfalfa-drying plants have been established recently, and while their finished product is in part fed locally, some finds its way out of the valley. Three large feed stores supply grain and allied products to the valley. The value of manure and fertilizer is now appreciated, and the results of the use of fertilizer are clearly evident where the farmer can afford it. A new and modern dairy supplies fresh milk to Tehuacan and the adjacent region. Several large poultry plants that have been built within recent years supply eggs and poultry to Tehuacan and markets in other cities.

Although the city of Tehuacan is the center of population, there are villages throughout the valley and on

Fig. 7. Arroyo de Atexcala. This broad dry arroyo joins the Rio Zapotitlan just above Chilac. The hills on its far side are part of the Cuesta de San Marcos in which Tecorral Canyon lies.

the uplands that surround it. Clinging to the mountainside in the oak-forest zone, with houses nestled into excavated foundations, like so many marmot dens, are villages like Apala, which look down on Coxcatlan and Calipan (Fig. 8). The highland people farm carefully contoured plots and come down to the valley to work and to trade upland products and fruits for manufactured goods and produce of the tropics. This relationship has persisted for many years, probably from pre-Columbian time. In at least some instances highland towns are subsidiaries of valley towns, and once supplied products to them for inclusion in tribute (see Cook 1958).

The valley is like a gigantic mixing bowl of languages, primarily of the Macro-Mixteca superstock (Swadesh 1959), into which a stirring paddle has been inserted. It has been a principal artery of trade between the high central plateau and the Valley of Oaxaca, used by Indian, Spaniard, and Mexican since time immemorial. The lingua franca of the traders has been based on Nahuat or Spanish. Mediterranean-based culture, brought from Spain, has fitted into the valley and given it its prevailing flavor, but aboriginal overtones still remain. Valley towns may be occupied by people of one aboriginal linguistic stock, or by those of several stocks. Thus, to list only a few valley towns, according to Tamayo (1962: III, 465) Tlacotepec, Tepanco, San Gabriel Chilac, and Zapotitlan Salinas are occupied by Popolocas de Puebla; Mixteca occupy a part of Tehuacan; and Mazatec-speakers occupy the southeastern end of the valley. Their principal towns are Teotitlan del Camino, Cuicatlan, and Huautla de Jimenez—the last-named in the highlands northeast of Teotitlan. According to Cook de Leonard (1953: 425) the people of Coapan are Nahua-speakers. Small enclaves of Chinanteca and Cuicateca are to be found in Cuicatlan (Tamayo 1962: III, 454–75). A remnant of Ixcateca-speakers lived at Santa Maria Ixcatlan until very recently, but there is no information to show whether or not this settlement has vanished within the last few years like others in its vicinity (Cook 1958).

Opportunities for the easy exchange of ideas, manu-

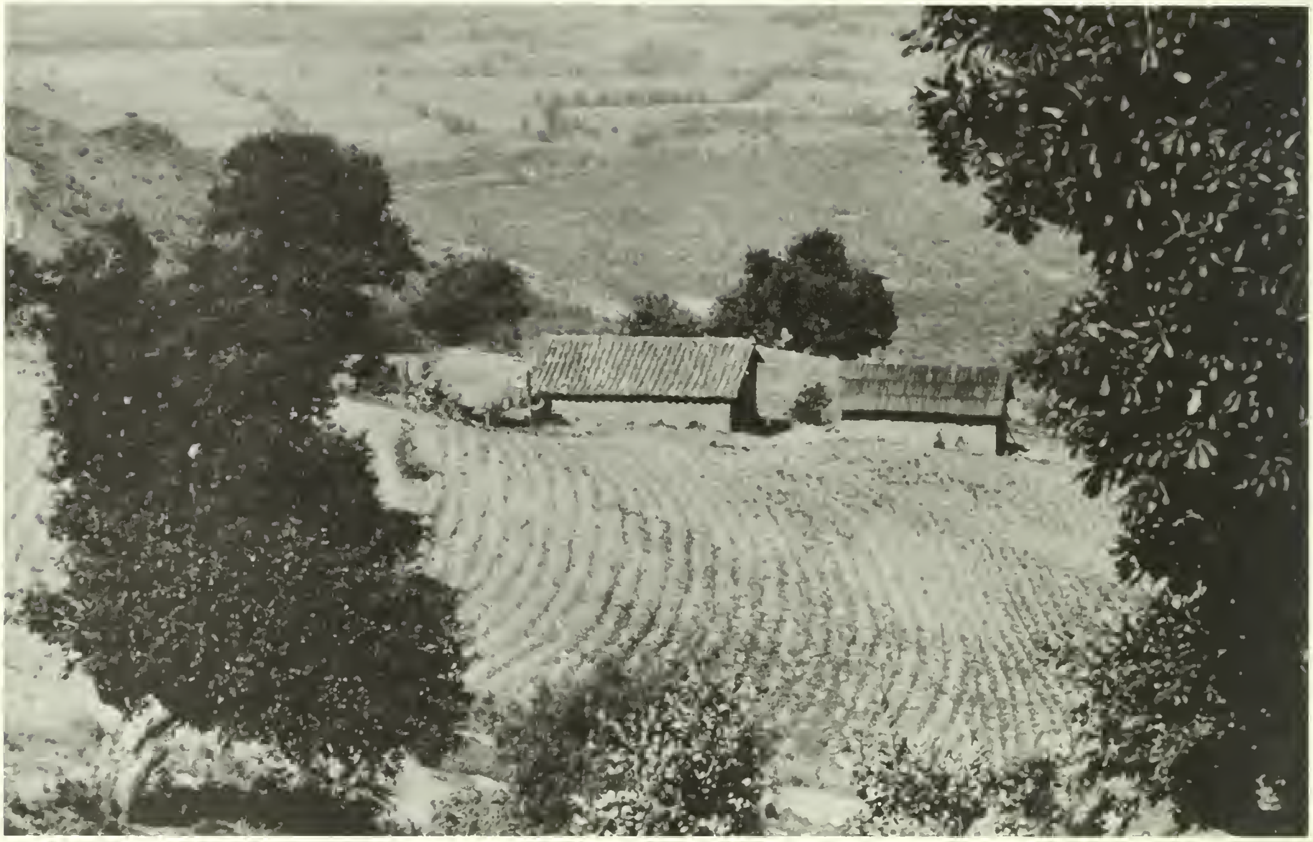

Fig. 8. Houses of Apala look down on the Tehuacan Valley.

Fig. 9. Buildings with adobe walls and thatched roofs saddled by maguey boards on northern outskirts of Tehuacan. The right-hand building has a vestibule of cane; sloping thatch fills the end of the gable.

factured goods, produce, and other elements of culture exist in weekly markets held in most of the larger towns. Such opportunities must have existed in aboriginal times, providing agencies through which many archaeological traits achieved wide diffusion.

The complexion of larger towns is uniformly Mediterranean, and in them exterior walls of adobe or concrete blocks and roofs of tile or sheet metal prevail. Aboriginal patterns of house construction still persist, however, and examples are to be found on the outskirts of towns or in the occasional house set off by itself. Houses may be walled with adobe, cane, cornstalks, thatch, or, in the warmer parts of the valley, with palm leaves. Roofs are usually thatched, often with a saddle of maguey boards (flattened maguey leaves). Palm-leaf thatch is the accepted roofing material in warmer parts of the valley. Differences in styles of house construction may be correlated with the cultural heritage of the linguistic group of the householder, or with his economic status. The relative ease with which various kinds of building material can be obtained also exerts some control over the choice (see Cook 1936–39).

During the recent past the population of the Tehuacan Valley has undergone many vicissitudes. The original population consisted of scattered bands or groups, perhaps numbering twelve to twenty-four people in all, who eked out an existence by collecting wild plant foods and trapping or killing any living thing within reach (MacNeish 1962: 31). This population grew, but largely retained its genetic identity (see below, Chapter 6), in spite of the addition of cultural traits received through contacts with other groups of people. It ultimately reached a figure estimated by MacNeish to be 5,000 times the original population, or 60,000 to 120,000 people just prior to the Conquest (MacNeish 1962: 41).

Many of the towns existed long before the Conquest. All are not listed in the many works of S. F. Cook in collaboration with L. B. Simpson and Woodrow Borah, a circumstance that can undoubtedly be attributed to the material on which these scholars have based their research—tribute rolls of the empire of Montezuma and the Spanish revisions of these rolls.

Most of the Tehuacan Valley fell under the Señorio de Teotitlan del Camino, an independent state allied to the Aztec empire, but not tributary to the Culhua Mexica. For this reason, no doubt, the extremely significant works of Cook and his colleagues overlook such present-day populous towns as Altepexi, Chilac, Miahuatlan, and Zinacatepec, almost all of which are most certainly old towns, founded in Postclassic times, if not, in some cases, before.

	1548	*1565*	*1568*	*1580*	*1595*
Axochitlan (Axusco)		4,218			
Chapulco	752		565		983
Coxcatlan	2,538	1,870	1,472	1,298	
Cuicatlan	1,043		1,020		
Ixcatlan	726		564		
Quiotepec	990	1,078	891		
Tecamachalco	47,825	48,423	17,688	19,750	14,400
Tecomavaca	594	586	413		
Tehuacan	6,650	12,627	7,788	2,288	
Teotitlan del Camino	4,158	4,009	2,798		
Tepanco		10,406			
Tlacotepec		10,862			
Zapotitlan	4,445	8,400	6,056		4,945
TOTAL	69,721				
Add 1565 figures not represented in 1548 source	25,480				
Possible total in immediate post-Conquest times	95,201				

SOURCES: 1548, Borah and Cook 1960; 1565, Cook and Simpson 1948; other years, Cook and Borah 1960.

Fig. 10. Shelter of cane and thatch in the southeastern end of the valley.

The accompanying list gives towns in the valley according to the various studies, with the populations at the indicated dates. It is difficult to reconcile some of these figures, but we assume that the area and population covered in one count may not be the same as that in another count for the same town. For example, note Tehuacan, with figures varying greatly from list to list, as is the case with Zapotitlan.

In arriving at a total for the valley, we have added the towns listed by Cook and Simpson that do not appear in other lists, but have not used the higher values for Tehuacan, Zapotitlan, Tecamachalco, and Quiotepec given in their count.

It would be possible to take the figure arrived at by this somewhat mixed approach and adjust it by a series of arithmetic manipulations, but the validity of such a procedure would be very questionable. While Cook and Simpson were able to reach a figure for the population of Mexico at the time of the Conquest by such means, we cannot be sure that the population of the Tehuacan Valley underwent identical stresses. It seems safe to say that MacNeish's figures are very likely too conservative.

Following the Conquest, the population of Mexico suffered a pitifully rapid decline. Impressment of Indians for forced labor brought death to many, especially to those sent to work in the mines. Entire urban communities died of hunger and cold when they fled to mountains and forests to escape the conqueror's chains. Diseases brought by Europeans and by African slaves further cut the ranks of the survivors. During the epidemic of 1576–78, for example, 60,000 persons died in the single city of Tepeaca and its suburbs (Cook 1949: 26). Authorities in Spain took steps to prevent further deaths of potential producers of wealth, but before corrective measures could be applied, the decline in population was drastic. The population of Mexico at the time of the Conquest is variously estimated to have been in the neighborhood of 9,120,000 (C. A. Nieve, quoted by Tamayo 1962: III, 384) or 11,000,000 (Cook and Simpson 1948). The estimate of Cook and Simpson has been generally accepted, but not, at first, without ridicule from some. As time has passed, more and more scholars have turned to the opinion that the estimate of Cook and Simpson is too low, and one has suggested that their estimate for the Mixteca should be doubled (Cook and Borah 1960:2*n*). It is evident that there was a very dense aboriginal population, in excess of 11,000,000. Borah and Cook (1963) have now increased this figure to 25,200,000. If we assume that the population of the Tehuacan Valley had declined by roughly the same proportions, our estimate of the pre-Conquest population in the valley would greatly exceed MacNeish's estimate.

Dobyns (1966) would increase the estimated aboriginal population of Central Mexico from the Borah and Cook figure of 25,200,000 to approximately 30,000,000. His study emphasizes the extent of depopulation following the first smallpox epidemic. If a substantial part of the population was wiped out by the epidemic of 1545, as may well have been the case, it appears that MacNeish's figures are indeed conservative and perhaps should be doubled.

By 1548 the population of Mexico is estimated to have been about 6,300,000 (Borah and Cook 1960, corrected by Cook and Borah 1960, "Correction"). Sixty years later it is set at 1,375,000 or 1,075,000 (Cook and Borah 1960). A figure of 4,500,000 in 1799 is given by M. Abad y Queipo (Tamayo 1962: III, 384).

There is a distinct possibility that these differences may be attributable to differences in the area covered by the estimates, and that some groups are included by Abad y Queipo who were excluded by Borah and Cook. Space to reconcile these differences is not available here. As we have seen, some towns in the Tehuacan Valley seem to have been omitted from the Borah and Cook, and Cook and Borah figures, but this seeming exclusion may result from their inclusion in the count for other communities.

Brief descriptions of some of the valley towns are given by Antonio de Alcedo (1786). Coxcatlan is described as inhabited by 180 families of Indians, 60 of Spaniards, mestizos, and mulattoes. Cuicatlan is described as the home of 125 Cuicatec Indians who make much saltpeter and cultivate much corn, beans, and cotton, from which they make excellent kerchiefs which are their chief item in trade. Of Santa Maria Ixcatlan, Alcedo writes that including its suburbs, it comprised

500 families of Indians who concern themselves with cultivation and trade in grain and vanilla.

Quiotepec . . . has 42 families of Zapotec Indians who trade in fruits and grains.

Tecamachalco . . . situated on the skirt of a hill so abounding with water that it runs in the streets and is brought into the houses and with it they cultivate many irrigated pieces and gardens that produce infinite flowers, fruits, vegetables, garden stuff, and grain that make the countryside very fertile and pleasant, the population includes 122 families of Spaniards, 17 of mestizos, 30 of mulattoes and 245 of Indians.

Tehuacan de las Granadas, so called for the abundance of exquisite pomegranates (granadas) which it produces, has abundant saline springs which are the center of much commerce, as are the fruits and seeds which the people of Tehuacan produce and the fishery which they carry on in the streams which make the town fertile . . . The waters that enrich and irrigate the fields are gentle and of pleasing taste but they are full of particles of nitrates, and so they coagulate and petrify the soil in the ditches and conduits through which they pass so that they form borders as hard as if they were of masonry, and from time to time they must be moved so that they may run; as a result of this the fields appear to be full of foundations like ruins of ancient buildings: this same nitrate that is coagulating on the fields is a solvent of stones and sands in the bladder . . . they do a big business in flour and meal because of the great deal of wheat that they gather in the haciendas of the district (and in the Valley of San Pablo alone there are twenty-two) and with this they supply the Plaza of Vera Cruz and the adjoining provinces as far as Havana and Campeche: there live in this city a great many families of Spaniards, mestizos, and mulattoes and more than 2080 families of Indians excluding more than 300 of the former and many more of the latter who live in haciendas in the country . . . Villages under its jurisdiction are: San Gabriel Chilac; San Miguel Eloxuhitlan; San Martin Mazapetan; Santa Maria Conjomeapa; San Pedro Teotitlan; San Pedro Clapulco; Coxcatlan; Acatepec; Miahuatlan; San Pablo Zoquitlan.

Tepeaca, Province and Alcaldia Mayor . . . of vast extent and generally warm climate although it has places that are temperate and others where it is cold—it abounds with sheep from whose wool they make textiles that are the principal business; it produces also much wheat, barley, and other grains, whose harvests are abundant, and no less of fruit, flowers, and garden stuff: in the celebrated Valley of Balzaguillo which is extensive, there are 56 farming haciendas . . . the population includes 80 families of Spaniards, 102 of mestizos, and 481 of Indians. . . . In the provincial capital there are 26 farming haciendas occupied by 177 Indian families who there collect abundant harvests of wheat, barley, and other grains, and of the first (wheat) alone, 1000 fanegas a year.

Alcedo lists four towns named Tlacotepec, of which only one corresponds in its description to Tlacotepec in

Fig. 11. A fossil irrigation ditch near El Riego was part of an ancient system originating near San Lorenzo.

the Tehuacan Valley. Alcedo attributes to it the advocation "de Santa Cruz": "Administrative center of part of the *Alcaldia Mayor* of Tepeaca, it lies at the foot of some stony sterile hills, has a hot dry climate, extremely scant water supply, for they use the scant rain which they collect in a great cistern from which they parcel it out economically to the inhabitants who are made up of 18 Spanish families, 27 mestizo or mulattoes, and 162 Indians who speak Chocha and Mexican and support themselves by butchering cattle and sheep and by the large harvests of grain that they collect."

Figures used by Tamayo show that by 1871 the population of Mexico had reached a total of 9,097,056. Part of this increase may be attributable to people of European and African blood who came to or were born in Mexico. The total stayed close to this level until 1880, when it began a slow but steady increase. In 1895 the first general census listed the population of Mexico at 12,632,427. By 1950 it had reached 25,791,017. The eighth general census listed 34,923,129 in 1960 (Tamayo 1962: III, 384). These last two censuses showed Tehuacan increasing from 23,209 to 31,724, San Gabriel Chilac increasing from 5,790 to 6,131, and Ajalpan from 5,073 to 6,391 (*ibid.*: 417). The growth of cities like Tehuacan can be attributed in part to the movement of people from rural regions in search of employment, but the increase in the population of such towns as Chilac is probably to be ascribed to improved conditions affecting public health and to the possibility of growing more food as a result of improvements in irrigation works and farming practices.

The present-day population of the valley is grouped into towns, between which stretch well-kept plots of cultivated irrigated land or uncultivated semi-desert, where goats graze among shrubby growth, including mesquite which is cut on occasion so that they may eat

Fig. 12. Oxen carrying the plow on the yoke, near Peñafiel.

the leaves and young shoots. The concentration of the populace into modern towns may be a post-Conquest phenomenon. It may reflect efforts of the Spanish conquerors to bring Indians into small groups so that they might be more easily controlled, or, on the other hand, it may possibly reflect the drawing together of people who worked the haciendas whose gutted ruins are to be seen throughout the area. Archaeological remains, especially of Postclassic or Venta Salada time—immediately pre-Conquest—can be found close to many existing towns, and it therefore seems more likely that the settlement pattern is very old, especially in view of the fact that some towns are mentioned in pre-Columbian documents.

As in much of Middle America, men who work the land make long daily trips to their fields and return home at night. Valley men take burros, mules, or even horses with them when there are loads of fodder or crops to be brought back, and do not, as a rule, bring such things in with a tump line, on their backs.

Men work their irrigated lands according to the time assigned them for receiving water from the irrigation ditches. The farmer turns his land with a simple wooden plow shod with a steel or iron point, using a yoke of oxen. In place of the yoke that rests on the neck of the oxen and is held in place by a bow that circles the neck, the Tehuacan farmer uses a yoke that is lashed to the brow and horns of the animal. Plowing is done under a variety of conditions. Land is owned in common by the *ejido*, or it may be privately owned. While groups of men bring their oxen and plows to a given plot at a given time, the circumstances under which the plowing is done vary with the ownership of the land. Whatever the circumstances, the plowmen are experts. They can turn a field, without benefit of any visible instrument other than the plow and oxen, so that water spreads evenly over it without gullying. Within recent years the practice of manuring the fields and of using chemical fertilizers has been accepted, with consequent increase in the productivity of the land. The cost of fertilizer is a factor that militates strongly against its wider use.

To the west of Tehuacan, on the road to Zapotitlan, are irrigated and well-cultivated fields beyond which lies the village of Santa María Coapan, a community of Indians to whom the populace of Tehuacan offers a ready market for tortillas and produce of many kinds.

The road down the Tehuacan Valley to Teotitlan del Camino drops abruptly over the edge of the terrace on which Tehuacan stands as it heads southeastward to San Diego Chalma and San Pablo Tepetzingo. Tepetzingo boasts a parking facility for donkey trains that come down from villages in the barrancas and on the sierra to the north and east. Below the Tehuacan terrace, irrigated fields line both sides of the highway. The main irrigation ditch flows parallel to the highway for a way, either hidden behind a screen of *carrizo* (*Arundo donax* L.) or in an open ditch that provides combined roadside water supply and bathing and laundry facilities. Beyond Tepetzingo the valley floor becomes wider as it enters a long and gradual slope to the edge of the Llano de la Taza (el. 1374 m.). Some ten kilometers from Tehuacan the road to San Gabriel Chilac and its dependent hamlet Xaco branches off. Again comes a rather abrupt descent to the eastern outskirts of the town of Altepexi (el. 1230 m.) and its dependent *aldeas*, the first sizable settlement through which the highway passes. Altepexi lies 446 meters below Tehuacan, and its climate is consequently warmer. Near Ajalpan are several good-sized tile and brick works, clay for which is mined from the adjacent plain. Walls of the clay pits have exposed many archaeological remains, and it is in these pits that the sites known as Ajalpan, Las Canoas, and Coatepec were found. Cut walls of these pits reveal, toward the top, thin bands of mineral soil and seemingly vegetal material, one above the other in alternating sequence. These rhythmite-like deposits which have built up the surface of the plain may well be the result of irrigation with water from a river that had not yet cut the deep barranca in which the Salado now flows.

Remains of irrigation ditches, "fossilized" by precipitation of minerals in the water, seen along the back road between Tehuacan and San Lorenzo, are those to which Alcedo refers. Remains of other irrigation ditches are thickly scattered across the Llano de la Taza. Some lead to San Gabriel Chilac. Others wind

Fig. 13. The Cuesta de Altepexi. On its surface is the Llano de la Taza.

down the face of the terrace above Altepexi, preserving in stone every twist and turn of the watercourse.

Following south along the highway from Ajalpan, one comes next to San Sebastian Zinacatepec (el. 1120 m.). This very "Indian" town is inhabited by Mazatec-speakers. To the west is San Jose Miahuatlan, close to the Rio Zapotitlan, across which is the hamlet of San Mateo Tlacoxcalco.

One sees an occasional patch of sugar cane after leaving Tepetzingo, but cane only becomes a principal crop to the south and east of Zinacatepec, for the elevation at Zinacatepec is sufficiently low to assure warm nights for the cane. A sugar mill operates at the former hacienda of Calipan (el. 1100 m.), which lies above the floor of the valley on its northeastern side. Cane for this mill is grown in every suitable location throughout the southern end of the valley and in other favorable locations, such as the lower ends of the principal barrancas.

Southeast of Calipan is Coxcatlan (el. 1200 m.), like Calipan set on the northeastern foothills 200 meters above the valley floor. Farther down are the two towns of Tilapa (el. 890 m.) and Teotitlan del Camino (el. 1067 m.), also set on the foothills. Coxcatlan and Teotitlan are both ancient towns. Their sites are adjacent to large archaeological sites with pyramidal mounds, plazas, and terraced ridges. It therefore seems likely that they are modern communities that are continuities of towns dating from at least Postclassic times.

A short way below Coxcatlan the valley grows narrower as low hills encroach from both sides. Arable land is thus restricted to the immediate vicinity of the river and to terrace-like margins of tributary streams. In the eastern hills are the rock shelters known as Coxcatlan Cave, Abejas Cave, and Purron Cave. The large Postclassic site of Venta Salada lies on a nearly level terrace-like remnant between the Rio Zapotitlan and the Rio Salado, almost directly across from the village of Coxcatlan.

At the crossing of the Arroyo Lencho Diego, in which lie Purron and Abejas caves, the elevation of the highway has dropped to 850 meters above sea level. The confluence of this arroyo and the Rio Salado about 1.7 kilometers to the westward is 50 meters lower. However, Cerro Prieto, between the Calapilla and the Salado, forms the precipitous right bank of the Salado only three kilometers downstream. Hills begin to close in from the left bank of the Salado, also. Ignacio Mejia lies about nine kilometers downstream from the confluence and, at an elevation of 742 meters, considerably below it. Teotitlan is 325 meters above Ignacio Mejia on the Rio Teotitlan, which empties into the Salado at the latter community. Here the river begins to cut downward; the elevation of its bed drops 175 meters in something over twenty kilometers to Santa Maria Tecomavaca. As it passes San Juan los Cues, it has cut a gorge that in places approaches a depth of 200

Fig. 14. Modern pans for evaporating brine from saline springs near Zapotitlan Salinas.

meters. Less than ten kilometers farther downstream the Salado joins the Rio Grande, at an elevation of somewhat less that 500 meters, before turning eastward to cut through the Sierra Madre de Oaxaca which towers more than 1600 meters above the river on either hand. Cultivated land is not plentiful in the lower reaches of the river, although there is some at Tecomavaca. While the valley was surveyed for archaeological sites as far downstream as Tecomavaca, for all practical purposes archaeological work was concentrated betwen Teotitlan and Tehuacan, or El Riego, which adjoins it.

From Tehuacan to Teotitlan the distance by road is approximately 64 kilometers; in a direct line it is nearly 16 kilometers less. The average gradient of the valley floor is in the neighborhood of 19 meters per kilometer, but this is misleading, as the first 300 meters consist of the descent from the Tehuacan terrace to the Llano de la Taza, and the next 133 meters come in the descent over its edge—two rather steep descents, the cuestas of San Marcos and of Altepexi, separated by a long, slowly descending stretch. From Altepexi to Teotitlan the descent is at a more even rate.

The Rio Zapotitlan follows a generally southeastward course toward the Rio Salado almost from the moment it breaks into the valley above Chilac. Between Venta Salada and Axusco the river continues on a closely parallel course, turning abruptly at Axusco to flow eastward to join the Salado near Tlachica. A narrow strip of arable land lies along the Zapotitlan; southward from Axusco this becomes wider for a short way. There is little water for irrigation here, saving the flow of the rivers which must be taken from them many kilometers upstream in order to raise the water to the level of the fields.

Large haciendas formerly occupied the valley, and their ruins may be seen today among fields and towns. Almost without exception they were burned and sacked during the revolution of 1910–17, when their lands were expropriated for the restoration of *ejidos* to villages from which they had been taken.

On the west side of the Tehuacan Valley are several groups of saline springs. Most prominent and most readily accessible are those near the modern towns of Zapotitlan Salinas and Salinas de Barranca in the Zapotitlan Valley. At localities in this vicinity salt is prepared by evaporating the brine that flows from the springs and then partially purifying the salt. The salt industry dates from pre-Columbian times, as is demonstrated by the myriad of mounds in the Tehuacan Valley that were built to support filters through which brine was passed in order to remove impurities. The filtrate was concentrated by boiling it in pottery vessels and then heating the concentrated brine until the water evaporated and a salt cake resulted. The cake could then be carried in trade, or sent in tribute to the overlords. Near Cerro Pelon, and to the west of Petlanco, salt mounds in almost innumerable quantity are concentrated around another group of saline springs.

The link with the pre-Columbian past is very strong in the valley. Although the inhabitants of the valley appear to be thoroughly acculturated, there are many Indians and Indian customs still persist in one form or another. Through this happy circumstance it has been possible to interpret the uses of many artifacts and to determine the uses to which many plants were put, thus bringing life to archaeological research as few are fortunate enough to be in a position to do.

Fig. 15. Remains of prehistoric salt pans west of Petlanco. The mounds which supported the filtering apparatus have been opened by treasure hunters.

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CHAPTER 4

Climate and Hydrology

Douglas S. Byers

THE Tehuacan Valley enjoys a hot dry climate. Rains occur there chiefly in two periods of six to eight weeks each between mid-May and mid-July and between late August and late September. Winters are ordinarily dry. Tehuacan itself, at an elevation of 1676 meters, experiences frosts during the winter months, but days are warm or even hot, except when the *norte* brings cold, cloudy weather. On occasion a *norte* will bring rain to the valley and snow far down the shoulders of higher peaks in the neo-volcanic axis. In short, during the winter, woolen clothes are often necessary for comfort.

With the approach of spring, winds increase, dust begins to fill the air, and smoke from burning *milpas* adds to the haze. When rains begin, the air is cleaned, and the oppressive feeling of the late dry season gives way to a bracing freshness. During the rainy season the temperature falls from its dry-season peak, and a sweater again becomes comfortable.

This climate is a product of several factors which modify and are modified by each other. We shall now turn to an examination of them and to the peculiarities of the Tehuacan Valley.*

Climate is a product of many variables in the atmosphere. These include temperature; humidity in the form of water vapor, clouds, and precipitation; and motion arising from differences in pressure and density existing between neighboring air masses.

The ultimate source of energy powering atmospheric circulation is heat received from the sun. This is received in greatest amount in the equatorial regions, which serve as a heat source. A pattern of general atmospheric circulation distributes that heat from the heat source toward the polar regions, which are heat sinks. The circulation displays salient features resulting from the rotation of the earth and the position and configuration of land masses. These include a deep zone of easterlies in low latitudes toward which winds converge from both hemispheres; zones of divergence, or high pressure, near 30° N. and S. Lat., from which flow the easterly trade winds of the tropics and the deep and broad mid-latitude westerlies; and a zone of polar easterlies, the latter separated from the mid-latitude westerlies by a poorly defined zone of low pressure at about 60° N. The subtropical highs are well developed over the oceans and generally absent over land masses, although their effects are felt far from the oceans.

Oceanic currents also transport heat away from equatorial regions. The pattern of these currents exhibits many similarities to currents in the atmosphere. They also have some effect on climates. Of these, the best known to us is the warming of northwestern Europe by the Gulf Stream.

The climate of the Tehuacan Valley is a product of the physical characteristics of the atmosphere and of the position of the valley with respect to the general atmospheric circulation, particularly with respect to the trade-wind belt of the northern hemisphere. Next in importance is its situation, between the Gulf of Mexico and the Pacific Ocean. The controlling factor, however, appears to be the topography of south-central Mexico. We shall discuss these subjects in order,

* I am indebted to Reid A. Bryson and David A. Baerreis of the University of Wisconsin for valuable criticisms and advice. They are in no way responsible for any statements or postulations advanced in this paper.

and then proceed to a discussion of rainfall in the Tehuacan Valley and environs.

It must be realized from the beginning that discussion of the climate of the Tehuacan Valley is based on data which are inadequate for a thorough study. Although series of observations for many stations in Mexico have been collected by the Servicio Meteorologico of Mexico since 1921, only a few series beginning in 1941 are available for the valley and surrounding parts of Puebla and Oaxaca. These are insufficient for a study of local climate. Therefore we must rely on the records of stations established in the Tehuacan Valley in 1955 by the Comision del Papaloapan. At these stations, data for rainfall, temperature, direction and velocity of the wind, and evaporation have been collected, although records in all categories are not kept at all stations. This information is published each year in the *Boletín Hidrológico.* Unfortunately, the *Boletín* covering the year 1961 is out of print and no copy is presently available. That for 1963 was not published at the time when this article was prepared. Because the total body of available data is inadequate, this analysis of climatic details of the Tehuacan Valley can be no more than tentative. While details accord with the larger picture of south-central Mexico, minute variations in rainfall within the valley—possibly of the utmost importance in explaining the location of sites and variations in the plant cover—can only be suggested. A long record of such data for the valley as a whole could be of considerable significance to ecologist and archaeologist alike.

Now let us turn to a discussion of climatic factors affecting the Tehuacan Valley, proceeding from the more general to the more particular.

The amount of water vapor that the air around us holds varies directly with the temperature of the air. Relative humidity expresses water vapor as a percentage of the amount the air is capable of holding. With close approach of relative humidity to 100 percent, condensation will occur. If the pressure or temperature of an air mass be lowered, it will reduce the ability of that air mass to retain moisture in the form of vapor. As the elevation of any air mass changes, there is usually an inverse change in its density and temperature. The change in temperature of dry air amounts to approximately 1° C. for every 100 meters change in altitude; that of saturated air changes 1° with every 150 meters of elevation.

Air will rise under several circumstances. When air is heated it expands and rises through overlying cooler air as a "thermal." Air will be made to rise when its flow forces it upward over a sloping land mass, such as the foothills of a mountain range. Air will also rise when a mass of cooler and therefore heavier air flows in at low levels, forcing the warmer resident air upward. Under all these circumstances the rising air expands, its pressure is reduced, it usually cools adiabatically, and water vapor condenses into droplets forming clouds or falling as rain.

Conversely, descending air is compressed and heated as its elevation decreases. This may happen to air forced over a mountain range and down the other side. As it grows progressively denser and warmer, its capability for retaining water vapor increases and it becomes a drying wind. This explains why a mountain range that is cloud-covered or rain-soaked on its windward side may remain clear on its leeward side. A wind that blows down a slope in this way is known as a *chinook* in the western United States and a *foehn* in the Alps. What the ancient inhabitants of Tehuacan called it was not discovered by the Project.

Where air ascends or descends there is little lateral transfer so that calms may prevail in such zones. The equatorial zone of rising air produces the showery equatorial belt known over the oceans as the Doldrums. The zones of subtropical highs, where air descends, are usually characterized by fair, calm weather known as the Horse Latitudes.

The stability of a column of air depends on its temperature gradient. The less rapid the fall of temperature with increase in altitude, the more stable the column of air. The temperature gradient of descending air masses is not abrupt and therefore such air masses are usually stable. The poleward borders of the trade winds, in general, belong in this category. They are dry and usually rainless.

When there is a steep temperature gradient from heated air at the earth's surface to cooler overlying air, the air becomes unstable. As the warmed air rises, it expands and is cooled. Its capacity for holding moisture is progressively reduced, so that clouds may form. If the process continues, a shower results. The equatorward borders of the trade winds belong in general to this category. They are often very humid, bringing rain. This is especially true on eastward-facing land and mountains.

Each year the thermal equator, with its zone of calms and ascending air and its bordering zones of trade winds and subtropical highs swings north and south in response to the seasons. In June, July, and August the thermal equator swings north to about 12°, bringing with it the zone of ascending, unstable air, with its towering cumulus clouds and rains. At this time, all of Central America and the southern half of Mexico

are under the flow of the moisture-laden and increasingly less stable portion of the trade winds. During the northern winter the thermal equator swings southward from this position carrying with it the zone of descending stable air of the subtropical highs. At this time all of Mexico and much of Central America is under the flow of the more stable portion of the trade winds. This annual swing produces the winter dry season and summer rainy reason of Central America and much of Mexico.

The trade winds blow across heated ocean water as they approach the coast of Middle America, taking up moisture from the warm water and carrying it toward the land. But it is only in the summer months that this air carries sufficient moisture to produce heavy rains. Nevertheless, some stations on the windward slopes of the Sierra Madre de Oaxaca or on higher elevations experience rain during most of the year. Air flow is in general from the land mass of Mexico to the Pacific Ocean. As a result, the effects of the Pacific Ocean water are felt in only a narrow coastal strip. In summer the wind may be on shore. Along the Pacific coast, winds carry surface water away from the land, resulting in an up-welling of colder water from the depths.

Atmospheric disturbances further complicate the pattern that we have just outlined. Air flows clockwise from the subtropical highs and some of this air of tropical or subtropical origin moves poleward. Similarly, air of polar origin flows outward, and, of necessity, equatorward. The zone in which they mingle is a turbulent one characterized by the passage of cyclonic storms and anticyclonic highs. Heavier polar air flows under the warmer tropical air, which rises and usually precipitates any moisture as rain or snow. Warmer air is carried northward on the eastern side of the storm and may at times flow completely around the center.

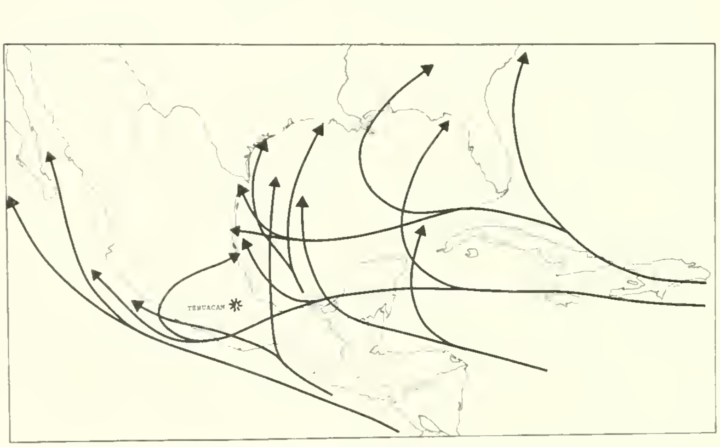

Fig. 16. Hurricane tracks, 1926–1955, after *Atlas Climatológico*, pls. 28, 29.

Polar air, at the same time, moves southward on the western side of the storm, and it, in turn, may complete a circuit. Such storms can grow to enormous size so that the system spans much of North America east of the Rocky Mountains.

In winter the zone of cyclonic storms and anticyclonic highs characteristic of middle latitudes is displaced southward with the subtropical highs and thermal equator. When a large and vigorous winter storm crosses the United States, masses of cold air may flow southward across the Great Plains to the Gulf of Mexico and produce the *nortes* which sweep the coast of Tamaulipas and Veracruz, reaching into the Caribbean, Central America, and even northern Colombia. They rarely produce rain in the Tehuacan Valley, but may do so in Central Mexico or along the Gulf Coast or on occasion bring snow far down the shoulders of the higher volcanoes. They often result in very cool weather in parts of the Tehuacan Valley.

The class of atmospheric disturbance with the greatest effect on the Tehuacan Valley is the tropical cyclone or tropical disturbance. Those originating on the Atlantic side of Central America are called hurricanes. Those having their origin off the Pacific coast are locally known as "chubascos." Origins, causes, and the mechanism of these storms are not fully understood. They appear to have their origin on the poleward side of the equatorial low as a wave disturbance on which a center of abnormally low pressure develops. Such storms may be born in the Atlantic Ocean, the Caribbean, or the Gulf of Mexico, or off the Pacific coast, often between the Gulf of Fonseca and the Gulf of Tehuantepec. Some never attain the full force of a hurricane, but others develop into very powerful storms with wind velocities of more than 180 kilometers per hour. Within the Tropics they are usually comparatively small symmetrical storms, with violent winds rarely extending more than 240 kilometers from the center, but as they curve northward the Atlantic hurricanes increase in size until wind and rain may extend more than 400 kilometers from the center. As this occurs the storm becomes increasingly asymmetrical.

Tracks followed by tropical storms vary from month to month and are, at best, unpredictable (Fig. 16). In their early stages the storms usually move westward with the trade winds at between 8 and 25 kilometers per hour, gradually curving northward, and eventually moving off to the northeastward. As the storms turn northward they pick up speed. Those that approach the coast of Central America and Mexico often follow northward just off shore, but some turn westward toward land. Those that intersect the land where there

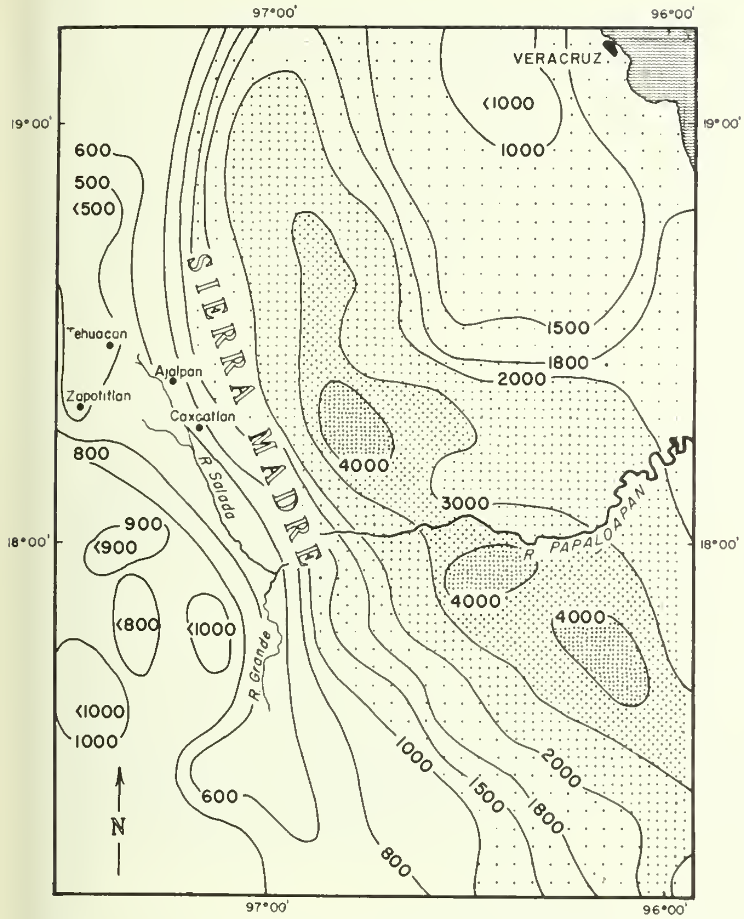

Fig. 17. Mean annual precipitation, 1926–1955, showing greater amounts of rainfall in eastern slopes of the Sierra Madre.

are no high mountains, as at the Isthmus of Tehuantepec, may cross to the Pacific and follow northward along the Pacific track, off the coast of Oaxaca, Guerrero, Michoacan, and Jalisco.

The quadrant of the storm that lies to the right of the direction of travel is the more dangerous. For example, as a storm turns northward its radius increases in the eastern quadrant until gales and rain may extend a great distance from the center. As it travels northward with increasing speed, wind velocities increase on its eastern side to compensate for its forward speed. On the western side of the northward-moving storm, wind velocity is less, precipitation is less, and rain and gales do not extend westward or southwestward as far as they do to the northeast.

Seasonality of tropical storms is marked. Although they may occur in almost any month of the year, their frequency is greatest in late summer and early autumn.

The period from late July through the first part of August is known in Mesoamerica as the *veranillo*, or "little summer." In this interval crops and plants that started their growth under stimulus of the early rains put on a rapid growth. Rains brought by tropical storms supply much-needed moisture as crops begin to mature toward the end of the period of rapid growth. In the absence of a supply of water for irrigation, a change of track of tropical storms that results in a drought in August and September may have near fatal effects on the crops in inland highland valleys like that of Tehuacan. Thus the tropical storms bring welcome and much-needed rain to southern Mexico when the beneficial effects of the June and July rains have begun to wear off. At the same time, these storms may bring torrential downpours which can do severe damage, destroying crops and eroding land. At these times, raging streams and flooded lowlands drown people and livestock alike. The occurrence of tropical storms is unpredictable, their courses are erratic, and they cannot be counted on to reach any one part of the country every year.

Topography exerts strong and often controlling influence on weather systems approaching the Tehuacan Valley. In the first place, the Sierra Madre de Oaxaca provides a barrier to the passage of storms from the eastward. Its peaks reach altitudes of 2600 meters or more, and the intervening ridges reach 2000. It casts a rain shadow across the entire Tehuacan Valley, more intense at the northwestern end, where less rain can be expected, than at the southeastern end. Most of the moisture brought from the Gulf of Mexico and the Caribbean by storms and trade winds drops on the eastern slopes of the Sierra, at elevations between 1000 and 2000 meters. In three localities shown in Fig. 17, taken from *Atlas Climatológico e Hidrológico* (pl. 10), the average annual rainfall, 1926–55, was over 4000 mm. In the exceptional year of 1952, more than 7000 mm. fell at Cataluña. Rapid decrease in the amount of rainfall occurs between the eastern slopes and the crest of the Sierra, where the average recorded is no more than 1000 mm. Some moisture from the Gulf crosses the crest, but rainfall is progressively less at stations down the slope and in the Tehuacan Valley. During the same period, 1926–55, annual precipitation at Coxcatlan averaged 833 mm., that at Teotitlan del Camino averaged 546 mm., and that over a large area in the northwestern end of the valley was less than 500 mm. The peak of aridity must lie close to the area around Tehuacan and Zapotitlan, where annual rainfall in these years averaged 440 mm. and 412 mm. respectively. In the exceptional year 1943 only 78 mm. of rain was recorded on the gauge at Zapotitlan. Furthermore, rainfall within the general area of the valley is often highly localized.

In the nearby Mixteca Alta there is more rain than

Fig. 18. Rain in the Tehuacan Valley may be highly localized.

in the Tehuacan Valley, but in only two rather restricted areas within the territory covered by our detailed map (Fig. 19) does annual rainfall equal or exceed 1000 mm.

Records of rainfall show a marked cyclical variation in precipitation, but parallel curves are not recorded at the six stations for which curves are given on plate 10 of the *Atlas Climatológico*. It thus appears probable that these differences reflect different origins for the storms that bring rain to southern Puebla and Oaxaca. We shall return to this matter in a discussion of rainfall below.

The detailed map of rainfall within the valley is based on records of stations established there in 1955. Stations with shorter records have been used as guides in drawing isohyets; the yearly map of rainfall in the *Boletín* has also been consulted. Discrepancies between the detailed map and the more general map are at once apparent, but they can be explained on the basis of differences in periods covered and in detail registered on the more general map.

To illustrate the division of the rainy season into two parts, Fig. 20 shows average weekly rainfall at Altepexi during the years 1955–60 and 1962. We were unable to obtain data for 1961. Altepexi lies approximately in the center of the valley and cannot be greatly affected by mountains on either side. In the process of averaging weekly totals, extremes of rainfall have been smoothed out, as for example, with rainfall of 280 mm. from one storm, part of which occurred in one week, with the balance in the next. If rain did not occur in the same two weeks in any of the six other years under review, this very substantial rain would be almost obscured. Thus this chart is not a valid chart of average rainfall, but of average rainfall over a very short period within what seems to be a dry cycle. Two peaks of rainfall are characteristic of the rainy season throughout this part of Mexico. Diagrams for other towns in the valley are not presented here since they vary only in the total amount of rain, not in the distribution of rain through the year.

During the dry season clouds hang on the Sierra Madre de Oaxaca. Cloud forest thrives on the higher parts of the ranges. However, the trade winds, now descending the slopes, are warmed adiabatically so

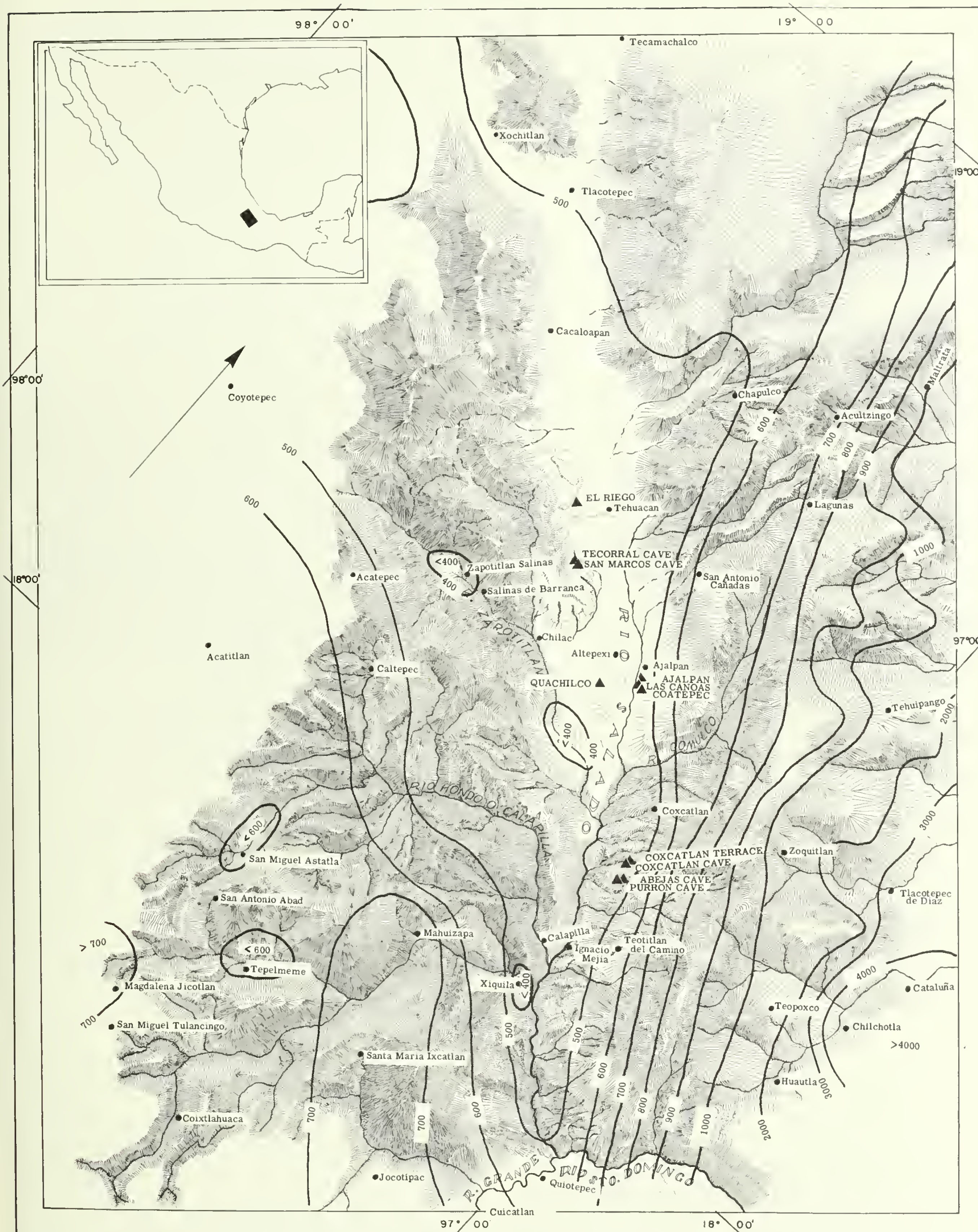

Fig. 19. Average annual rainfall in mm., Tehuacan Valley and environs, 1955–1962.

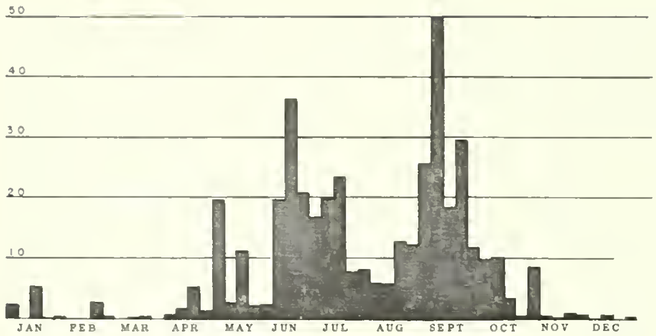

Fig. 20. Average weekly rainfall at Altepexi, in mm., 1955–1962.

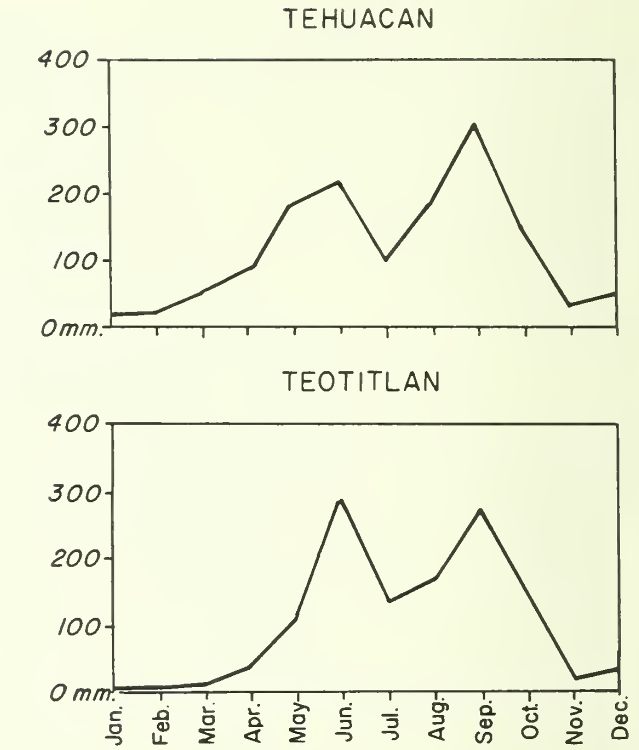

Fig. 21. Monthly distribution of maximum precipitation, 1926–1955 (*Atlas Climatólogico*, pl. 11).

that they become desiccating winds that bring the dust storms of March and April and make the heat in the valley oppressive and close.

Furthermore, the direction of what was once the northeast trade wind has been changed by topographic features to conform to the trends of the valley. The prevailing wind at El Riego and Tecamachalco shown in plate 6 of the *Atlas Climatológico* is southeasterly, and blowing at a force of 4.5–9.0 mph. At Coxcatlan it is easterly, at the same velocity. At Teotitlan del Camino the prevailing wind is westerly and at only 2.25–4.5 mph., possibly in response to the proximity of the mountain wall to the west.

Further study of rainfall analyzes what is termed "useful rainfall." Rains of less than 5 mm. are of little use to crops since they do little more than dampen the surface of the ground and evaporate quickly. Of rains of more than 5 mm. only 75 percent is considered to be available for crops, while 25 percent of the water runs away over the surface of the ground. Furthermore, this rainfall must occur at times when it can be used by growing crops. If the rain falls when crops are not in, a volume sufficient to supply the needs of crops will be of little use if there is no way of storing it. On the basis of usefulness, rainfall in the Tehuacan Valley is found to be even more deficient, for the farmer can count on an 80 percent probability of useful rain in only the following amounts: Tehuacan (El Riego), 119 mm.; Coxcatlan, 168 mm.; Teotitlan, 132 mm.; Tlacotepec, 175 mm.; and Zapotitlan, 107 mm. At Tehuacan, there is an 80 percent probability that useful rainfall of 24 mm. will fall during May, June, July, and September; in August and October approximately 10 mm. may be expected, while in April somewhat less than 10 mm. may fall. There is a 20 percent probability that droughts of twenty-eight or more days' duration may be expected in seven out of twelve months at Coxcatlan, and in ten at Tehuacan. The index of evapotranspiration shows the great deficiency of rainfall in the Oaxaca-Puebla Trough, for evapotranspiration everywhere exceeds rainfall by a substantial amount except during a brief period near the first of October.

According to the Koeppen classification, the southeastern end of the Tehuacan Valley belongs in the category Bswh′–steppe climate: rains during summer, xerophitic vegetation, hot with mean annual temperature of more than 18° C., and mean of coldest month above 18°. To the northwest of the confluence of the Rio Zapotitlan and the Rio Salado it falls in the category Bswh: mean of the coldest month below 18° C. A small area within the category Aw (savannah climate, with periodic rains and a dry winter) is to be found near Coxcatlan. According to Thornwaite, the climate of the valley floor falls into the category DdB'_3 (arid, rainfall deficient in all seasons, temperate, evapotranspiration high), while the flanks fall into $C_1dB'_4$ (semi-arid, rainfall deficient in all seasons, temperate, evapotranspiration very high). Only the extreme southern end of the valley falls within the category DdA′: arid, rainfall deficient in all seasons, hot. These subdivisions are of significance in measuring the degree of aridity. Around Coxcatlan and including the areas in which

Coxcatlan, Purron, and Abejas caves are situated, the Koeppen classification indicates a somewhat less intense degree of aridity.

Mean annual temperatures within the Tehuacan Valley vary inversely with the elevation of the stations. At Tehuacan (El Riego), el. 1676 m., mean annual temperature is given as 18.9°C.; monthly means vary between 15.8° in January and 22.0° in April and May. The mean for July is 20.4.° The maximum range is between 13.0° and 25.0°. At Chilac (el. 1219 m.) mean annual temperature is 21.5°, with a January mean of 17.0°, and a July mean of 22.3°. Means at Coxcatlan (el. 1200 m.) are 21.5° annual, 19.1° for January, 22.2° for July. The mean at Teotitlan (el. 1067 m.) is 23.8°, with January mean of 21.0°, July mean of 24.3°, and a range between 19.0° in January and 28.0° in May. Just below the confluence of the Rio Zapotitlan and Rio Salado, mean annual temperature is more than 25° C.

Examination of maxima and minima shown in Table I will demonstrate that there are departures from this generalization, and that these are most pronounced in the case of minimum temperatures. Freezing temperatures occur commonly in the higher, northwestern end of the valley in the months of December and January. These set a firm limit on the diffusion of tender perennials and trees. They also affect the planting of corn, for it cannot be grown safely at or above Tehuacan in these months, although it thrives just a short way down the valley, at lower elevations.

Minimum temperatures result from a number of factors. Temperature of the air which blankets the region is but one. Radiational cooling and air drainage are of great importance, particularly under comparatively cloudless conditions and in mountainous country. Doubtless these factors combined to produce the record −12.5° C. at Tepelmeme in 1961. Similarly, extremely low readings may occur in the mountain towns of the Mixteca Alta, apparently under favorable local conditions. Records of temperature in much greater detail than those available would be required for a proper study of this aspect of climate. Suffice it to say that Tepelmene experienced freezing temperatures in five of the twelve months in 1962, and only one-half a degree above frost in two more months. Comparably low temperatures are not recorded for stations in the Sierra Madre de Oaxaca—doubtless a reflection of the warmth and moisture carried in from the Gulf of Mexico by the trade winds.

A detailed study of rainfall within the Tehuacan Valley necessitates the examination of records of tropical storms, which, as we have seen, may be vital to the success of unirrigated agriculture. The *Atlas Climatológico* presents analyses of tropical storms over a thirty-year period ending in 1955. Unfortunately, few meteorological stations were in operation in the Tehuacan Valley at that time; therefore data for the valley itself are lacking. The Papaloapan Commission is quite properly concerned with the entire watershed, and not primarily with the arid Tehuacan Valley. In the Papaloapan watershed, the greatest flow is from rivers on the eastern side of the Sierra Madre de Oaxaca. A storm may affect those rivers, yet cause slight rise in the Salado and its tributaries. The converse is also true. Detailed records maintained from 1960 in the Tehuacan Valley offer a hint that Atlantic storms do not deserve as much credit for bringing rainfall to the valley as the Pacific storms do. It would take far longer records to demonstrate this, but in the records available there is a suggestion that this may indeed be the case.

We shall begin by considering the discussion of tropical storms in the *Atlas Climatológico*, and then proceed to the years 1955–60 and 1962. Although detailed data on storm tracks in the latter series is not presently available, we seem to have sufficient data on which to formulate an hypothesis.

Tropical storms originating in the Lesser Antilles, the Caribbean, the Gulf of Mexico and off the Pacific Coast have some effect on the Tehuacan Valley. In the *Atlas Climatológico* are courses of seventeen such storms which occurred between 1926 and 1955 and affected the watershed of the Papaloapan. Some of these are full-blown hurricanes, others were storms that had not reached hurricane force, while still others were large areas of low barometric pressure in the Gulf of Mexico that resulted in extensive movements of air masses producing prolonged rainfall over a wide area in the Papaloapan watershed.

Tropical storms that reach the Papaloapan basin—not necessarily the Tehuacan Valley—most frequently originate in the Caribbean, the Lesser Antilles, or in the Atlantic beyond them. Almost all are powerful storms of great force. Hurricanes Hilda and Janet, of September 1955, which affected the area around Panuco, and an unnamed hurricane of 1941 which came ashore in the state of Veracruz are typical of storms originating in the Lesser Antilles. Storms originating in the Caribbean Sea follow a similar pattern. Such a hurricane, in September 1944, brought severe floods to the Papaloapan watershed. Tropical storms originating off the coasts of Campeche and Tabasco sometimes dissipate quickly; others grow into full-blown hurricanes, like hurricane Gladys of early September 1955, which produced severe flooding in affected watersheds. Storms that originate in the Gulf of Mexico have a sub-

Table. 1. Maximum, Minimum, and Mean Temperatures (°C) at Selected Stations, 1952-1962

(Boldface figures are records for the period)

	1952			1953			1954			1955			1956		
	Max.	Min.	Mean	Max.	Min.	Mean	Max.	Min.	Mean	Max.	Min.	Mean	Max.	Min.	Mean
Acultzingo							35.9	-0.6	17.1	35.9	-0.4	17.0	**38.9**	1.4	16.8
Astatla (San Miguel)													31.0	**3.0**	16.1
Axusco															
Cacaloapan															
Calapilla										42.6	4.5	25.9	41.0	**3.0**	25.2
Caltepec										34.0	-4.0	18.1	33.5	**-4.5**	17.9
Cataluna	**39.0**	**4.0**	19.9	36.0	6.0	19.7									
Cd Serdan	30.0	-4.0	13.0	**34.0**	-2.0	14.0									
Coixtlahuaca				32.4	–	16.4	**33.0**	0.3	15.7	32.0	-4.0	15.4	30.5	**-8.0**	15.1
Coxcatlan	**43.0**	7.0	22.3	**43.0**	7.0	23.4	42.0	6.0	21.3	40.0	6.0	21.8	–	–	22.7
Coyotepec													31.0	**4.0**	16.3
Cuicatlan	42.5	8.5	25.5	–	9.0	–				**43.5**	9.0	25.2	37.0	7.5	22.8
Chapulco				35.0	0.0	17.5	34.0	0.0	17.0	35.0	0.0	17.5	35.0	1.0	16.9
Chilac										39.0	1.0	21.8	**39.5**	**-0.5**	22.1
Chilchotla										31.1	**0.9**	17.1			
El Riego	**38.0**	3.0	19.5				36.0	1.0	19.4	36.0	1.0	19.2	36.5	**-2.0**	19.2
Huautla	33.0	**3.0**	17.1	**35.0**	**3.0**	17.4				33.5	5.0	17.4			
Huapanapa													33.5	**-1.0**	19.2
Ignacio Mejia													41.0	**0.3**	23.8
Jocotipac													31.5	1.0	16.1
Lagunas													**29.0**	**-7.0**	11.8
Maltrata															
Quiotepec	44.0	6.5	25.0	**44.5**	5.0	25.8	43.5	6.0	24.9	44.0	5.5	24.9	43.0	5.0	24.5
Salinas De Barranca										38.0	0.5	23.2	36.5	1.5	20.4
San Antonio las Canadas													37.0	**1.0**	17.8
Tecamachalco	34.0	3.0	16.9	34.5	-5.0	17.5	34.0	-3.0	16.9	35.0	-4.0	–	34.0	**-9.0**	16.9
Tehuacan															
Tehuipango										**30.0**	**-1.0**	14.9	29.0	1.0	13.2
Teopoxco													30.0	**1.0**	15.8
Teotitlan	42.5	8.0	24.0	**43.5**	5.5	24.7	42.0	4.5	23.6	41.5	5.5	23.7	40.0	**3.0**	23.0
Tepelmeme	33.0	-8.0	16.3	33.0	-2.0	16.9	32.0	-6.0	16.1	**33.5**	-8.5	16.4	32.5	-9.5	15.5
Tepeji															
Tlacotepec	33.0	1.0	17.7	34.0	-2.0	18.1	**34.0**	1.0	17.3	**34.0**	0.0	17.3	33.0	**3.0**	17.0
Tlacotepec De Diaz							38.3	9.0	—	**40.0**	8.0	25.9	39.0	8.5	24.3
Xiquila										41.0	5.5	24.3	41.5	**4.0**	24.7
Xochitlan	31.0	1.5	17.6	**38.0**	0.0	18.3	35.0	-2.0	16.7	33.0	**-3.0**	16.6	31.5	-1.0	16.5
Zapotitlan													37.0	**-7.0**	20.7
Zoquitlan													30.0	**1.0**	15.6

	1957			1958			1959			1960			1961			1962		
	Max.	Min.	Mean	Max.	Min.	Mean	Max.	Min.	Mean	Max.	Min.	Mean	Max.	Min.	Mean	Max.	Min.	Mean
Acultzingo	35.0	1.0	17.8	37.0	3.0	18.0	33.5	3.0	–	36.0	**-1.5**	17.6	36.0	-1.5	17.6	36.0	1.0	18.2
Astatla (San Miguel)	31.0	0.0	16.7	**33.5**	-1.0	16.9	31.5	1.0	16.5	32.0	0.0	16.5	32.0	1.0	16.8	32.0	0.0	16.9
Axusco							40.5	7.5	24.8	**43.0**	**2.0**	23.9	40.5	**2.0**	23.2	39.5	4.0	23.3
Cacaloapan										34.0	**-1.0**	18.1	**35.0**	0.0	18.0	34.0	2.5	18.2
Calapilla	42.5	7.0	26.2	**43.0**	6.0	26.0	41.0	8.0	24.5	**43.0**	3.5	23.8	42.5	3.5	25.1	42.0	8.0	25.5
Caltepec	**39.0**	1.0	18.7	35.5	0.0	18.2	36.0	1.0	18.1	34.0	-3.0	17.8	34.0	3.0	18.2	35.0	1.0	18.6
Cataluna	36.0	4.5	19.3	35.0	5.0	19.1				38.0	**4.0**	19.3	38.0	7.0	19.4	36.0	8.0	21.9
Cd Serdan				32.0	-4.0	13.2	32.0	-5.0	13.3	30.0	-4.0	13.4	29.0	**7.0**	12.4	29.0	5.0	12.9
Coixtlahuaca	31.0	-0.4	16.0	32.0	1.0	16.2	31.0	0.0	15.7	31.0	-2.0	17.2	**33.0**	-0.5	16.0	32.0	1.0	16.3
Coxcatlan	40.0	5.0	22.1	42.5	**4.5**	25.2	41.0	10.0	25.3	**43.0**	7.0	25.5	**43.0**	6.0	24.5	42.0	8.5	25.7
Coyotepec	30.0	0.0	15.9	**33.0**	0.0	15.9												
Cuicatlan	43.5	10.0	26.9	43.0	9.0	24.5	41.5	11.0	25.8	43.0	**7.0**	25.9	43.5	9.0	26.3	43.5	9.5	26.2
Chapulco	34.0	1.0	17.7	34.0	1.0	17.7	**36.0**	2.0	16.1	35.0	**-4.0**	18.0				34.0	-2.0	17.1
Chilac	**39.5**	0.0	23.1	39.5	2.5	22.7												
Chilchotla	**36.0**	5.0	18.2	33.0	2.0	18.0	30.0	4.0	17.2	33.0	3.0	17.6	35.0	5.5	17.7	33.0	3.5	17.8
El Riego	36.0	2.0	19.8	36.0	1.0	19.6												
Huautla	31.5	3.5	15.6	32.5	3.5	16.3	29.5	5.0	16.7	32.5	5.0	17.5	32.5	4.5	17.0	34.0	**3.0**	17.1
Huapanapa	33.0	–	20.0	**34.0**	3.0	19.6												
Ignacio Mejia	**42.9**	2.3	24.9	42.0	3.0	24.6	41.0	6.5	24.5									
Jocotipac	**33.0**	1.5	17.2	31.0	4.0	16.8	31.0	3.0	16.8	30.5	3.5	17.2	30.3	**-9.5**	17.2	31.5	-6.5	16.6
Lagunas	27.5	5.5	12.9	**29.0**	-3.0	12.8	27.0	3.5	12.0	28.0	-4.5	12.2	**29.0**	-5.5	12.4	28.0	-5.0	12.4
Maltrata																35.0	0.0	14.8
Quiotepec	44.0	6.0	25.5	43.5	6.5	25.1	41.0	9.5	24.9	44.0	9.0	24.7	43.5	**4.5**	24.2	42.0	7.0	25.1
Salinas De Barranca	37.5	2.5	21.5	37.0	3.5	21.2	36.5	4.5	20.8	32.5	1.5	20.7	**38.5**	**1.5**	21.3	37.0	4.5	21.4
San Antonio las Canadas	33.5	2.0	19.6	34.0	2.0	18.4	31.5	4.0	18.0	**37.5**	1.0	18.0	29.5	1.5	17.8	32.5	3.0	18.1
Tecamachalco	35.0	-4.0	17.6				34.5	-2.0	17.2	34.0	5.5	17.2	34.5	-6.0	17.1	**35.5**	-2.0	17.3
Tehuacan																33.0	-1.5	17.8
Tehuipango	29.0	3.0	14.7	29.0	3.0	13.1	29.0	4.0	13.3	28.0	2.0	12.8	**30.0**	1.0	14.0	28.0	0.0	14.1
Teopoxco	**36.0**	1.0	17.1	34.0	2.0	16.8	31.0	4.0	16.3	33.0	2.0	16.5	33.0	1.0	17.2	32.0	3.0	16.7
Teotitlan	40.0	5.0	23.8	40.5	5.0	23.8	38.5	8.0	22.3	41.0	**3.0**	23.2	40.0	9.0	23.3	39.5	7.0	23.9
Tepelmeme	33.0	-6.5	16.4	**33.5**	3.0	16.6	31.0	3.5	16.4	32.5	-8.5	16.3	33.0	**-12.5**	16.0	29.5	-4.5	13.2
Tepeji							36.0	6.0	–	37.0	**4.0**	22.0	**38.0**	6.0	22.3	35.0	7.0	22.7
Tlacotepec	33.0	-1.0	17.8				32.0	3.0	17.0	33.0	-2.0	17.0	**34.0**	-2.0	17.2	33.1	1.0	17.3
Tlacotepec De Diaz	**40.0**	10.0	25.0	39.0	8.0	24.7	37.0	12.0	24.2	**40.0**	**6.0**	24.6	**40.0**	10.0	24.8	39.0	9.0	25.4
Xiquila	**43.0**	6.0	26.0	**43.0**	6.0	25.5	41.5	9.0	25.4	**43.0**	**4.0**	25.2	**43.0**	4.5	25.2	42.5	7.0	25.5
Xochitlan	32.0	-2.0	17.2	35.5	0.0	17.6	33.0	2.0	17.5	33.0	-2.0	16.5	34.0	0.0	17.1	33.0	0.0	17.1
Zapotitlan	**38.0**	2.0	22.0	**38.0**	2.0	21.5	37.0	3.0	21.3	**38.0**	-1.0	22.0	**38.0**	1.0	21.7	37.0	3.0	21.9
Zoquitlan	**40.0**	4.0	17.3	30.0	3.0	16.7	29.0	7.0	16.3	–	–	16.1	33.0	4.0	17.5	31.0	3.0	16.9

Fig. 22. Minimum temperatures, in degrees Centigrade, Tehuacan Valley and environs, 1955–1962.

stantial effect on the Papaloapan watershed only if they are formed off the coast of Veracruz. Storms originating in the Pacific may follow the west coast or veer suddenly to the eastward and cross southern Mexico. These do affect the Papaloapan watershed, although they do not produce as heavy rainfall as the storms which originate in the Caribbean or the Lesser Antilles.

Routes of seven storms that occurred from 1932 to 1955 have been charted and rainfall analyzed. We here discuss some of these storms as they affected the Tehuacan Valley; rainfall east of the Sierra Madre was far heavier. In September 1944, a hurricane was born in the Caribbean west of Jamaica. On the nineteenth it was in the Yucatan Channel; on the morning of the twentieth it came ashore on the tip of Yucatan near Puerto Juarez. By the night of the twenty-first it had dissipated over the Isthmus of Tehuantepec. However, it appears to have regenerated as a less violent storm and moved northward, with its center off the coast of Veracruz. This storm brought rain to the Tehuacan Valley in the following amounts: on the twenty-first, 10–30 mm., with the heavier fall on the immediate flanks of the Sierra; on the twenty-second, from less than 30 mm. to more than 50 mm., with the heaviest fall on the flanks of the Sierra Madre and on the Sierra Mixteca, while no rain fell in the center of the valley between Tecamachalco and Ajalpan; on the twenty-third, between 50 and 100 mm. fell on the Sierra Mixteca and in the lower valley, but in the upper valley, from Altipexi northwestward the fall was 10 mm. or less.

A hurricane took form in October 1950, south of the area in which the hurricane of September 1944 was born. It crossed Yucatan, passing over Tulum and Merida. It then swung westward and southwestward to come ashore south of Veracruz. On October 10 it produced rain in amounts varying from nothing in the vicinity of Tecamachalco to more than 50 mm. at Teotitlan, except for an area around Calipan, Coxcatlan, and Venta Salada, where no rain fell. On October 11 light rains of 0–10 mm. fell in much of the valley, but the rainless area extended northwestward along the eastern side of the valley from Coxcatlan. On October 12, rains of 0–5 mm. fell from Tehuacan southeastward along the flanks of the mountains and spread westward to include much of the Zapotitlan Valley. Altogether, on October 10, 11, and 12 the storm produced 10–20 mm. of rain between Tecamachalco and Tilapa, with up to 50 mm. in the Sierra and between Tilapa and Teotitlan. In the extreme southern end of the Salado Valley rainfall exceeded 50 mm.

In 1955, Hurricane Gladys took shape off the coast of Campeche and Tabasco on September 1, and followed a course that took it northward parallel to the coast. It produced heavy and general rains throughout the valley and more than 80 mm. throughout the Mixteca Alta. A remarkable feature of this storm was a center of heavy precipitation in the Zapotitlan Valley. In the accompanying tabulation the daily precipitation in millimeters during the life of the hurricane at selected stations in the valley illustrates the spotty nature

	Sept. 3	*Sept. 4*	*Sept. 5*	*Sept. 6*	*Sept. 7*
Altipexi	13.0	60.0	25.5	32.5	2.0
El Riego	17.5	23.0	44.5	34.5	3.5
Calapilla	11.3	38.2	30.3	32.4	10.3
Chilac	41.2	6.0	74.5	31.5	3.6
Quiotepec	2.1	9.0	25.6	44.5	19.5
Salinas	26.6	15.5	83.4	67.1	1.4
Teotitlan	28.5	34.8	32.5	35.5	13.5
Zapotitlan	33.0	20.0	80.0	66.0	2.0
Coxcatlan	58.5	58.5	32.5	38.5	52.0

of the rain produced by such storms. Although juxtaposition of Chilac and Quiotepec in this tabulation appears to point to a movement of the storm, or at least an active cell, from north to south, we do not have data adequate to determine such movement.

Other tropical storms which do not reach hurricane force may produce more rain in the Tehuacan Valley than full-blown hurricanes. However, the pattern of rainfall produced is as irregular as the rain which results from hurricanes. While on a given day during such a storm no rain may fall at any given spot, although heavy rains may fall nearby, the succeeding day may bring from 20–50 mm. of rain.

Heaviest rainfall may come during the hurricane season, between late August and October. In the thirty-year period 1926-55, a total of 450 tropical storms of hurricane or near-hurricane intensity were recorded. Of this total, 127 storms originated in the Lesser Antilles or beyond; five reached the Papaloapan watershed, two passed within 100 km., six passed at a distance of 100 to 400 km., and 114 swung northward more than 400 km. away. The Caribbean was the birthplace of ninety-eight storms, of which five reached the Papaloapan watershed, eight passed within 100 km., and fourteen at a distance of 100 to 400 km. Off the coasts of Campeche and Tabasco seventeen storms took shape; three of these reached the Papaloapan watershed, two passed within 100 km., and twelve passed between 100 and 400 km. away. None of the storms originating within the Gulf of Mexico passed within 100 km. of the Papaloapan watershed; as a result, their

effect is slight. A total of 135 storms originated in the Pacific Ocean and followed a course parallel to the west coast. Of these only three passed within 100 km. of the watershed, two were between 100 and 400 km. away, and 130 were more than 400 km. distant. Storms originating in the Pacific and coming ashore numbered fourteen, of which four reached the Papaloapan watershed and five passed within a distance of 100 km. Of the 450 storms, 3.8 percent reached the Papaloapan watershed, 4.4 percent were within 62 km., 10.9 percent were 100 to 400 km. away, while the great majority, 80.9 percent, passed at a distance of more than 400 km. and had little or no effect on the Papaloapan drainage.

Unfortunately, the data regarding tropical storms is not included in numbers of the *Boletín Hidrológico* covering the years 1955–59 and *Boletín* 13, for the year 1961, is not available. Therefore, we have only *Boletín* 12 and *Boletín* 14, for 1960 and 1962, on which to base our analysis.

During 1960 seven tropical disturbances occurred on the Atlantic side and seven moved up the Pacific coast. Among Atlantic storms were five whose tracks took them far from the Tehuacan Valley—as far away as the southeastern United States and the open ocean. During the periods of their life no significantly heavy rain fell in the Salado watershed, nor did any fall during the life of the storm known as Annette, born well off the isthmus of Tehuantepec on June 9, to travel on a northwesterly course far from land, passing from the record books June 13. Shortly after Annette's passing, Bonnie was born off the coast of Guatemala, June 18, to move up the Pacific coast and die in the Gulf of California on June 25. General rains, sometimes heavy, occurred in the Salado watershed June 12–29. General rain occurred July 4–7 when there was no tropical storm. Hurricane Abbey, born in the Virgin Islands July 11, died against the Sierra Madre de Oaxaca July 16, as Hurricane Celeste was taking shape in Honduras. This storm passed up the Pacific coast and lost its identity as a hurricane July 21. General and heavy rain occurred in the Salado watershed July 16–20. General rain fell again between August 14 and 26. Although heavy rainfall in the valley during July coincided with the passage of Hurricane Diana off the coast of Oaxaca, July 17–19, the heaviest rainfall at Altepexi, Calapilla, Salinas de Barranca, Teotitlan, and Zapotitlan fell August 24 when no tropical storm was reported.

Another period of rain began August 29. The twenty-eighth was the day of heaviest rainfall of the year at Huautla de Jimenez, although only one of the valley stations—Calapilla—reported measurable rain and then only 0.4 mm. Rains were general on the twenty-ninth and thirtieth when Estela took shape in Honduras. This storm passed close to the Oaxaca shore before going northwestward into the Pacific on September 9. General and heavy rains occurred at valley stations September 5–8, but there was no rain at all at Huautla.

On September 19 Coxcatlan received 140 mm. of rain; Altepexi, 88.0; Calapilla, 56.5; Salinas de Barranca, 55.9; Teotitlan, 90.6; Xiquila, 51.5; and Zapotitlan, 57.0. Huautla received only 13.8 mm. This rainfall may have resulted from the tropical storm known as V2 which took shape in Yucatan Channel September 16 and ran westward to the Sierre Madre de Oaxaca, where it ended its career on September 20.

The only other year between 1955 and 1962 for which we have detailed records of tropical storms and of rainfall for the valley is 1962. During that year, thirteen tropical disturbances were reported between 15° and 25° N. Lat. and 90° and 105° W. Long. Routes of the majority of these storms took them some distance from the Tehuacan Valley. Within the valley itself substantial rains occurred coincident with only two storms—V2 and Berenice—both on the Pacific slope. There were also rains at Acultzingo and Lagunas coincident with these two storms. Although only light rains were reported in the valley, more generous rain occurred on the Atlantic slope coincident with the passing of V3 from Tabasco to Tampico, close in shore. One may see a possible correlation between the two events. Rain fell generally in the valley and on its western and eastern rims from August 31 through September 3 and continued locally for a day or two more at various stations. The *Boletín Hidrológico* records no tropical storm in this interval. It should be noted that few tropical storms passed close enough to the valley in the year 1962 to have any effect. Without detailed data it is not possible to be certain that rainy spells coincident with such storms are in reality caused by them. Generally stormy conditions associated with areas of low barometric pressure may in reality bring the rains. From these low-pressure areas tropical storms may develop under favorable conditions, attracting more attention than larger, less violent storms.

Thus it may be seen that the hurricane season cannot be counted on to bring rains to the valley. Further detailed study is required to determine whether Pacific storms are of major importance as sources of rain.

We have observed above that a marked cyclical aspect is characteristic of the rainfall of the region. The interval of the cycle is not clearly evident in any readily available data. The *Atlas Climatológico* makes refer-

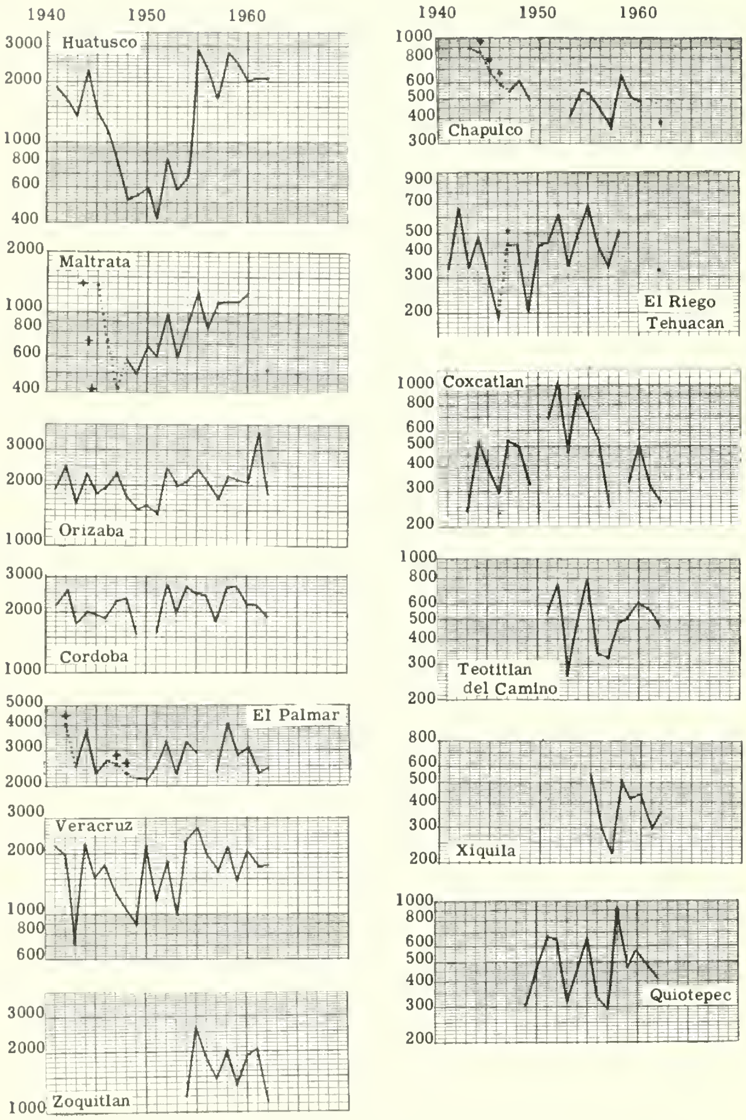

Fig. 23. Annual rainfall at selected stations, 1941–1962, in mm. on logarithmic scale. *Left:* east of the crest of the Sierra Madre de Oaxaca. *Right:* west of the crest.

ence to a period of abundant rainfall from 1926 to 1937, followed by a period of deficiency from 1937 to 1951, followed by abundant rainfall from 1952 to 1955. Annual precipitation for the period 1941–62, as published in *Boletín Hidrométrico* 14, makes it clear that rainfall was low at many stations over the span of a few years, but that abundant rains come at intervals, except at Huatusco which is outside our map area, on the Gulf slope, where a period of low rainfall persisted 1945–54. In many stations in the Oaxaca–Puebla Trough this interval was interrupted by a year of good rains in 1947.

If rainfall is plotted on a logarithmic scale, the importance of amounts of rainfall is eliminated. Instead, we shall have graphic representation of the rate of variation from year to year and in this way be enabled to compare stations with minimal rainfall with those where rainfall is abundant. These graphs appear to demonstrate that the rainfall over the area fluctuates according to at least two and possibly three rather characteristic patterns—that exhibited by stations in the valley and especially the southeastern valley and that exhibited by stations on the eastern slope. A third possible pattern may be exhibited by Oaxaca and stations on the western slopes. A far longer record would be necessary to establish the reality of this division.

Rain, when it does come, may strike with the force of a cloudburst, cutting gullies and eroding unprotected slopes. Its effect on sloping fields on the flanks of hills is maximum. Although we lack information regarding intensity of rainfall for many of the valley stations, *Boletín Hidrométrico* 14 lists, for four stations in the valley, the figures for maximum intensity in terms of millimeters per hour according to minutes of duration. These we present in the accompanying tabulation.

Minutes duration	*Calapilla 7/5/59*	*Quiotepec 5/29/49*	*Salinas de Barranca 6/10/59*	*Xiquila 9/3/62*
5		240.0		
10		156.0		
15		132.0		
20		112.5		
30	62.0	86.4	100.0	55.0
45		62.2		
60	61.5	47.7	62.0	38.0
80		36.5		
90	4.5		48.6	26.1
100		30.0		
120	33.8	25.8	37.6	20.0
240	17.6		20.7	10.3

Thus Quiotepec, with 240 mm. per hour for five minutes received 20 mm. of rain in that interval. Over a ten-minute interval the intensity was 156 mm. of rain. Rainfall over two hours at the rate of 25.8 mm. per hour brought 51.6 mm. At Salinas de Barranca, not far from Zapotitlan Salinas, the maximum intensity of 100 mm. per hour for 30 minutes produced 50 mm. of a total rainfall of 86.5 mm. on June 10, 1959. At Xiquila, on September 3, 1962, 27.5 mm. of a total of 43 mm. for the day fell in one-half hour. The greater part of that total fell in four hours, leaving only 1.8 mm. to fall during the rest of the day.

Such quantities of water, falling on dry or nearly dry ground, unprotected by vegetation, are capable of pro-

ducing intense washing in a very short interval. Soon gullies are filled with tumbling stones and a flood of mud. Larger gullies carry fair-sized boulders, and the barrancas, boulders of the size of a hogshead. If this water can spread out over a broad flood plain at a slackened pace some of it will sink in. Such is the character of the terrain in the Tehuacan Valley that this rarely occurs. According to the tables of discharge, the response of the streams in the valley is almost instantaneous, and the flow as quickly dies. Thus, although the Rio Zapotitlan carried 13.1 cubic meters per second on June 10, 1959, it carried only 0.485 cubic meters per second on June 11.

Extensive disturbance of the natural plant cover accompanied the extension of agriculture to new parts of the valley, and Miranda (1948: 344–46) has observed that nearly pure stands of cacti may result from human intervention. Disturbance in the oak-pine zone would have been severe, especially if ancient agricultural practices were based on the milpa system of slash-and-burn, as seems likely in view of its widespread use by Indian farmers today. With the increase in population and developing agriculture, additional inroads on plant cover were made by cutting forest trees to clear new cropland, for firewood, or for fuel for burning lime for structures faced with plaster or stucco. When steep mountain sides were eventually brought under cultivation, such disturbance rendered the soil easily susceptible to washing. Where the regolith on which soils developed was not derived from acidic rock, caliche-like *tepetate* has formed, making the soil almost impervious to moisture at relatively shallow depths. Such circumstances in combination must have caused the water table to begin to drop, a phenomenon that probably had its inception in Classic times at the latest. Loss of marginal fields to erosion and a lowered water table can only have served as a stimulus to the development of irrigated fields on the valley floor.

The introduction of sheep and goats by Europeans must have accelerated processes of erosion. During the course of a botanical survey of the upper Papaloapan watershed, Miranda made apposite observations concerning erosion. In discussing the higher parts of the basin, he remarks (1948: 346–48):

. . . about 1400 meters in the Cuicatlan district and above 2200 meters in the country around Tehuacan the xerophitic vegetation stops abruptly and is replaced by oak and pine forest. Farms in this zone almost exclusively produce rainy-season crops, especially corn and beans, which they supply to markets in the low country. Forests in this zone are being actively felled in order to establish new tillage; as the land is in general very sloping, erosion is progressing rapidly.

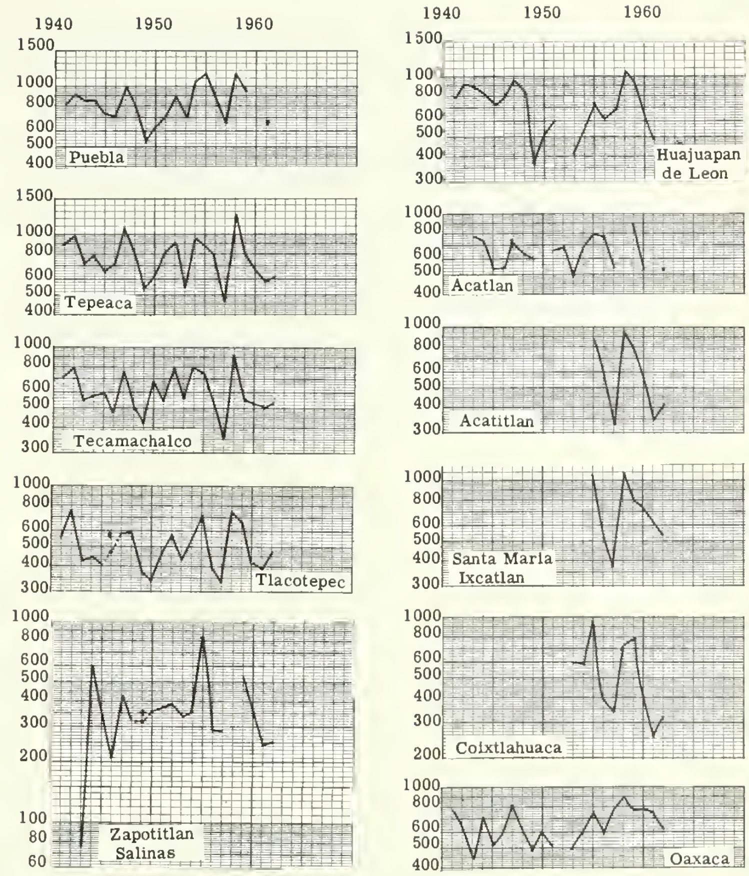

Fig. 24. Annual rainfall, 1941–1962, west of the crest of the Sierra Madre de Oaxaca. *Left:* except for Puebla and Tepeaca, in the Puebla-Oaxaca Trough. *Right:* except for Oaxaca, west of the trough.

Heavy rains remove great quantities of yellow loam and this is the dominant color of the rivers and brooks. Red sandstones near Cuicatlan give a red color to the waters of the brooks, but not to the big rivers. With heavy rains toward the higher parts, and with no rain in the lower, the volume of rivers increases immediately and their turbulent waters become tinged with yellow. It seems, therefore, as if immoderate clearing and farming activities on steeply sloping land in the upper parts of the basin were responsible for the increased erosive action in places where the aridity of the climate and the irregularity of the rains are already producing by themselves active erosion.

In other days, groves of oak and pine must have evenly covered all high country over the limits noted above. They are now greatly reduced by clearing; nevertheless one may still find great expanses of very beautiful forests in places farthest from the towns [my translation].

On page 362 Miranda observes that erosion is very intense in all the upper parts of the watershed. These seem to be the source of the greater part of the detrital

Fig. 25. Farming is sometimes undertaken on steeply sloping fields.

material carried by the rivers whose waters never become clear in any season of the year. He notes that from natural causes erosion is most intense in this zone because of the relatively immature rolling relief, the aridity of the climate which does not allow a dense vegetal cover to develop, and the irregularity of the rains which come all at once at certain times of the year and send the rivers over their banks. However, it is his view that responsibility for the enormous increase in erosion must be assumed by man, especially the residents of the high country with their ill-directed farming practices, their immoderate clearing of the forests to establish new tillage, their farming activities undertaken with no precautions at all, even on steeply sloping fields, and also at times their fires and the overgrazing of their sheep and goats.

That the dropping water table and consequent drying up of springs and wells dates back at least two centuries is clear from records of abandoned towns in northern Oaxaca, just west of the Cañada. The present town of Santa Maria Ixcatlan lies only 24 kilometers, as the buzzard flies, to the west and north of Cuicatlan. It is situated in a small valley enclosed by hills on three sides and drained by the Rio Ixcatlan, a tributary of the Rio San Pedro, which in turn drains into the Rio Grande not far south of Quiotepec. The town has been the subject of a detailed study by Cook (1958), who describes its situation as "the center of an extensive mountain mass of triangular shape, the apex of which is formed by the confluence of the Rio Hondo and the Rio Salado about 10 kilometers south of Teotitlan del Camino. The eastern side of the triangle follows the Rio Grande southward to the vicinity of Tomellin, and the western side follows the Xiquila to its headwaters near Coixtlahuaca. The base is an arbitrary line from Coixtlahuaca to the headwaters of the Rio Apoala, thence to the Rio Grande at Tomellin."

Cook gives the elevation of the plaza of Santa Maria as 1950 meters, but the elevation in *Boletín Hidrométrico* 14 is 1850 meters. It is clear that this does not vary greatly from the higher parts of the Tehuacan Valley. However, annual precipitation is greater at Santa Maria Ixcatlan than at any station in the Tehuacan Valley itself. Fluctuations in rainfall occur at Santa Maria just as they do in the Tehuacan Valley, the extremes 1955–62 being 1063 mm. in 1955 and 378 mm. in 1957. Distribution of rainfall through the year corresponds to that at stations in the Tehuacan Valley, there being a peak in June and July, and a second peak in September and October. In response to this cycle, two plantings of corn were made—one in milpas set high on the mountains to make use of moister conditions, was made in late winter, February to March. It germinated on moisture in the soil and rain brought by the rare winter showers, but ripened and matured under the effects of the rains of the early season. The second planting was made just prior to the early rains, so that it might receive their moisture for germination and early growth. This crop grew to maturity on the later rains and was harvested in November and December. A similar planting schedule is typical of much of Central America under a climatic regimen in which there are two peaks of rain. (La Farge and Byers 1931: 77.) Failure of the first of the rainy seasons to materialize can spell disaster for both crops.

Cook was concerned with long-term changes in rainfall. He cites the occurrence of epiphytes and parasites on forest trees and the lack of seedlings as evidence of a deteriorating forest, and adduces information from natives that forests were once more extensive as possible evidence in support of a proposition that there has been a reduction in total rainfall. He goes on to suggest as an alternative the loss of effective rainfall to run-off as a result of processes of erosion set in train by the inhabitants themselves through many years of cutting firewood, through the practice of slash-and-burn agriculture, and finally through the devastating effects of running sheep and goats.

He then cites seven small towns—the *pueblos despoblados*—which formerly existed northeast of Ixcatlan. According to one of Cook's informants, four towns lay on the north side of the Rio Seco, "extending to near the Rio Salado"—San Miguel Nopalapa, San Jeronimo, Santa Cruz, and San Cristobal—and three were on the south side of the stream—San Juan Viejo, Santiago, and San Antonio Nopala. Cook visited the site of San Juan

Viejo and observed "across the deep canyon of the Rio Seco to the north . . . four open or bare places high on the side of the mountain. These can be none other than the worn and eroded sites of the four towns of the outer line," i.e., on the northern side of the river.

Cook further cites "irrefutable documentary evidence" dating from 1578 involving persons from Santiago, Nopala, and San Juan Coyula, the last-named said to be the equivalent of San Juan Viejo. Records of a surveying party sent out in 1743 to delimit the boundaries of Ixcatlan show that they visited a place "that they call Santa Cruz, an old and uninhabited town where there are two orchards of fruit trees." (This and the translations below from the Spanish are my own.) A document dated 1778, from Coixtlahuaca, states ". . . and although this town of Ixcatlan had other subordinate towns in their time, no one lives in the districts where they were, [they have] already gone wild and completely sterile, and only the ruins of their churches are to be seen."

Thus it is clear that these towns were abandoned at some time between the end of the sixteenth century and the end of the eighteenth. Cook cites two possible causes, including a change in climate resulting in less rain and a diminution of the *effective* water supply as a result of deforestation and erosion of the soil, but he does not feel that the evidence justifies the acceptance of one and the total exclusion of the other. He does state "certainly there is no visible sign of water at present, and no possibility of profitable agriculture in the arid, sterile basin of the Rio Seco. All this might argue for a diminution of water induced by a change in climate. The gradual desiccation seems clear, since before 1600 the area was able to support seven towns which originally may have been of fair size."

There is scant historical evidence bearing on the water supply; however, an excerpt from the *Relaciones Geograficas del Siglo XVIII* reprinted by Cook as Appendix I states in part:

> The aforesaid town (Santa Maria Ixcatlan) is not very abundantly endowed with sources of water, for it has only one river (which comes to an end after a descent of a half a league) and one poor well and all this water is of middling quality, and two very small arroyos also run somewhat brackish water (only in the rainy season).

The village is situated on a terrace-like formation on the Rio Ixcatlan. This appears to have been a zone of alluviation such as is described by Brunet in Chapter 5 below. Subsequently the river has cut through this terrace-like feature and in doing so lowered the water table. Modern wells used for the water supply of the present village are at the up-stream end of this terrace. Cook further discusses the possibility that the village was in a mature valley above which were forested slopes or heavy shrub and grassland resting on a mature soil. Disturbance of this primeval cover by human activity would then open Pandora's Box and let flood waters loose, with consequent erosion, deposition, and eventual gullying.

In the presence or absence of domesticated plants Cook sees a guide to both climate and rainfall. He refers to a tribute of two loads of cotton paid in 1553 by the town of San Miguel Huautla (not Huautla de Jimenez, a highland Mazatec town east of Teotitlan). Regardless of the correctness of translating Ixcatlan as "the place of cotton," Cook avers that if cotton could be grown in Huautla it could be grown in Ixcatlan. He goes on to say (p. 17) that "cotton of the ancient type requires more warmth and moisture than there is in Ixcatlan (or Huautla) today. Here a definite change in climate may be predicated."

In respect to plants and animals, the *Relaciones Geograficas* continues:

> Fruit trees include chicozapotes which fruit in the months of July and August, and also there is sugarcane, and black(ish) sapotes in the lower parts of town and in addition many *huaje* trees and some papaya trees; also there are pulque magueys, and *anonas* [custard apples] and all are not very abundant: such can only be said of the six-month corn, sown and harvested in this interval.

Cook states that "today there are a few (20–30) sapotes, very few *huajes* and *anonas* and no papayas or sugarcane." The "virtual extinction" of these semitropical domesticated plants he attributes to a change in climate, after averring that there is no loss of interest in fruit trees because people have kept the sapote, introduced the fig, maintained the mulberry, and introduced some drought-resistant trees in recent years. He then asserts that erosion and soil desiccation cannot be invoked and that a change of climate must have occurred.

According to Cook, the "rather profound alteration in the physical environment during the past few hundred years" has driven the people of Ixcatlan from diversified agriculture to corn alone, and from the raising of corn to the manufacture of hats made from leaves of the overabundant palmetto (*Brahea dulcis*), a plant of arid situations.

If, now, we turn from Cook's work to Brunet's hypothesis (Chapter 5) of a steadily lowered water table, we see that it is possible to interpret all phenomena listed by Cook as resulting from continued draining away of water resources and a lowered water table

brought on by headward erosion of streams. Effects of this cycle are further accentuated by the rapid run-off of precipitation, in turn causing a decline in effective precipitation which has the same effects on plants as a general decline in precipitation.

If this be the case in the Ixcatlan valley, it must also have applied in the Tehuacan Valley. By analogy we may infer that with a higher watertable, and with a larger effective rainfall, it is likely that the aspect of the Tehuacan Valley in 1500 was less harsh and arid than that of the present and that sapotes, chicosapotes, avocados, papayas, and doubtless other fruit trees and plants which are alleged not to grow in the Tehuacan Valley without irrigation were in reality to be found until about two centuries ago in suitable spots there or in the beds of barrancas leading down from the Sierra. In such barrancas they must in all likelihood have once been found farther down slope than they are at present, especially in the vicinity of Coxcatlan, Purron, and Abejas caves where there is now somewhat more rainfall than in the central, western, and northwestern parts of the valley.

Such a supposition is given further credence by Wagner's comments (1964: 253) concerning what may be relict species and associations in suitable locations in the upper Papaloapan drainage, almost surely including the Salado: "The original cover may have been very different from that of the present, and Miranda (1948) suggests that the local climax may have been a mesquite forest of *Prosopis juliflora*."

No one save Flannery (Chapter 8) has yet adduced any good reason to believe that the climate of the Tehuacan Valley has undergone much change in postglacial time. There is no evidence that the Valderan substage of Wisconsin glaciation of the Great Lakes Basin brought major climatic changes to the southwestern United States (Martin 1964). In the aboriginal condition of mesquite forest postulated by Miranda, there would have been areas of grassland such as are postulated by Flannery for the environment required by the antelope and jack rabbits of early Ajuereado time.

In the absence of any pollen record from early times in the valley one is forced either to postulate a period of cooler and somewhat moister climate—a postulation for which we have no support—or to accept Miranda's view.

In regard to a difference in climate and rainfall in Pleistocene times, Brooks (1949: 59) has pointed out that the onset of glacial conditions would intensify present winter conditions. The polar front would be pushed southward, increasing the contrast in temperature on the opposite sides, and thus increasing storminess. Next would come a small but intense anticyclonic belt with a narrow belt of powerful trade winds. The equatorial trough of low pressure would be deepened. As a result of these changes

> outside the great ice sheets there is evidence of a much greater rainfall (snowfall in the mountains) in two belts, one along the new storm tracks a short distance equatorward of the ice edges, and the other along the equator. The former gave rise to the great lakes of the Great Basin of America and of the interior of Asia, and to a large number of mountain glaciers, the latter to the greatly increased lakes of Central Africa and to the glaciers of Kenya, Kilimanjaro, Ruwenzori, and parts of the Andes. Between these two belts the evidence of greater precipitation is more indefinite and irregular.

One may observe that at present winter is the dry season in the Tehuacan Valley and in central and northern Mexico. Cold winters would not increase precipitation, for snow falls on Citlaltepetl, Popocateptl, and Ixtaccihuatl during the summer rains, and only rarely under winter conditions, when the snow usually melts.

There seems to be no grounds for extending to the Tehuacan Valley the "Pluvial period" of the climatic cycle developed in the southwestern United States by Antevs (1955). Recent work by Aschmann (1958), Martin (1963), Martin *et al.* (1963), and Mehringer and Haynes (1965) has cast doubt on the reality of the "Neothermal Climatic Cycle." A paper by Bryan and Gruhn (1964) points to fallacies involved in extending such a cycle, if indeed it exists, beyond the ecological zone in which it was developed as a means of dating aboriginal occupations or for the purpose of inferring climatic conditions for dated aboriginal occupations in North America.

To extend the Pluvial period of Antevs to the Tehuacan Valley seems particularly unjustifiable, because the southwestern United States lies in the flow of winds from the poleward side of the zone of subtropical divergence now lying near 30° N. These ultimately become westerlies and contribute to the cyclonic storms of mid-latitudes. The Tehuacan Valley, on the other hand, lies within the zone of trade winds originating from the same source, but flowing toward the zone of equatorial convergence. There is, therefore, a considerable barrier to any extension, however hypothetical, of the postulated climatic phases of Antevs to the Tehuacan Valley.

Several climatic models for the time of Pleistocene glaciation, including that of Brooks, postulate a narrowing of the zone of equatorial displacement of the sub-

tropical zones of divergence—the subtropical highs now near 30° of latitude. There must of necessity have been an accompanying narrowing of the belt of trade winds and an increase in their force. It is also postulated that the seasonal swing of the entire tropical and subtropical system of winds was reduced in amplitude. A reduction in the width of the zone of trade winds could only serve to move the drier portion of this belt farther south, and a reduction in amplitude of the seasonal swing would serve to prevent the moister portion from swinging so far north in the summer. There is thus a good possibility that in late Pleistocene time the Tehuacan Valley was even less well watered than it is today. It may have been less well watered, but possibly cooler, with a climate approaching that of San Juan sin Agua in northern San Luis Potosi.

Because of these possibilities it would require a series of radiocarbon dates for glacial features on peaks of the neo-volcanic axis, or a series of radiocarbon dates for a number of pollen profiles reflecting climatic changes, in order to establish an acceptable correlation of as yet undiscovered climatic phases in the Tehuacan Valley with hypothetical ones in the United States.

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CHAPTER 5

Geologic Studies

Jean Brunet

IN THIS chapter the term "Tehuacan Valley" applies only to that part of the entire Tehuacan basin which is bounded on the northwest by Tepanco de Lopez and San Andres Cacaloapan, both in the state of Puebla; on the eastern side by ranges of the Sierra Madre de Oaxaca, including from northeast to southeast the sierras of Acultzingo, Zongolica, and Mazateca; on the southwest by the Sierra de Zapotitlan; and at the southeastern end by the environs of Teotitlan del Camino, in the state of Oaxaca. The area so defined comprises the central part of a Cenozoic continental basin formed from an arm of the Cretaceous sea. The basin was rejuvenated during Quaternary time as the result of its capture by the Rio Santo Domingo and thus became part of the watershed of the Rio Papaloapan, into which the Santo Domingo discharges. The Rio Salado and its tributaries—surface, subterranean, or artificial—drain this northwestern sector of the trough.

This study is concerned not only with the valley itself, but also with a more or less extended strip along the shoulders of the bordering mountains and with the adjoining Zapotitlan Valley, briefly as the latter may be treated.

In the field we sought to carry out essentially parallel traverses, perpendicular to the axis of the valley, that is, oriented approximately northeast-southwest. These traverses allowed us to gather rather quickly the samples and observations necessary to prepare the geological study. Certain details, especially those concerning the hydrogeology, were studied near the town of Tehuacan—at the former hacienda known as "El Riego"—and near Ajalpan and Tilapa, all in the state of Puebla. It developed that they could furnish some facts directly concerning archaeology.*

The map shows that the region covered by this survey comprises approximately 1600 square kilometers, but the total area includes some 2000 square kilometers, thanks to the relief, which unfortunately could not be covered in sufficient detail because of the lack of time and especially of adequate means of access, particularly in the mountainous regions. After covering nearly 12,000 kilometers in this region by jeep, we took stock of the gaps in our observations, and as a consequence, of the resulting defects in this study.

The very long history that runs from the crystallization of the earth's crust, some four and a half billion years ago, until the beginning of Jurassic time is hidden from view in the Tehuacan Valley. At best, one may group certain geologic structures which are clearly very old under the term "basal complex."

We have studied this basal complex on the flanks of

* Professor José Luis Lorenzo, Director of the Departamento de Prehistoria, Instituto Nacional de Antropología e Historia, Mexico, made it possible for me to join the Tehuacan Archaeological-Botanical Project under the auspices of the R. S. Peabody Foundation and led by Dr. Richard S. MacNeish. To these two, as well as to the Peabody Foundation, I wish to express my deepest gratitude. It is also a pleasant task to thank again those who helped me carry out the geologic studies of the valley, especially Ing. Arturo Sotomayor, who kindly undertook a number of petrographic studies, the results of which are presented at the end of this chapter. I am indebted also to certain earlier studies of the Tehuacan Valley, especially the memoir by Barrera (1946) and the guidebook for the excursion by the Twentieth International Geological Congress (1956).

This chapter has been translated from the French by M. T. Einaudi and Marland P. Billings.

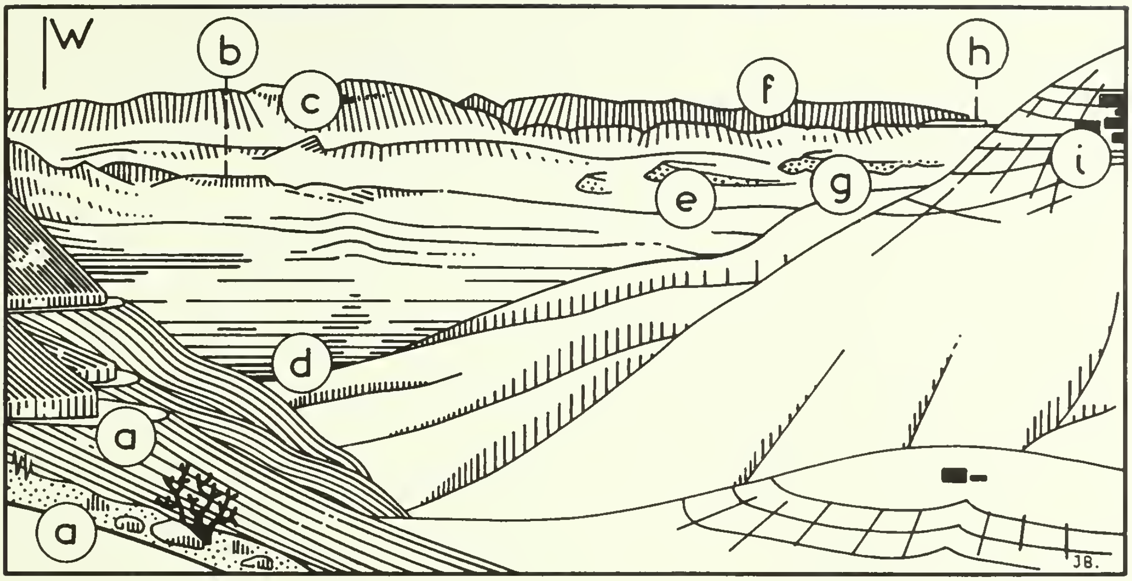


Fig. 26. Panorama of the Tehuacan Valley, looking northwest from km. 11 on the Teotitlan–Huautla road, *a*. Other points are: *b*, Cerro Tepetroje; *c*, Nudo Mixteco Mountains; *d*, approximate location of Purron and Abejas caves; *e*, Cuesta de Altepexi; *f*, Sierra de Zapotitlan; *g*, Cuesta de San Marcos; *h*, Cerro de la Mesa de Tuhuacan; *i*, hill and hamlet called Chichiltepec.

the Sierra Mazateca and along the road from the town of Coxcatlan to San Pablo Zoquitlan* and in the Sierra de Acultzingo, where it possibly represents the Paleozoic or the beginning of the Mesozoic (Triassic). It may go back a half billion years. It is principally composed of metamorphic rocks—schists, slates, sandstones with calcareous cement showing traces of dynamic metamorphism (see note 1 under the Analysis of Hand Samples below), sandstones contaminated by volcanic material (2), quartzite (3), gneiss, mica schists (4), and marbles (5), as well.as rocks often extensively altered and intruded by volcanic dikes. The latter are particularly evident along the road to Huautla de Jimenez, Oaxaca, in the Sierra Mazateca.

This basal complex has been submitted to numerous tectonic and volcanic disturbances, of which folds, traces of dynamometamorphism, dikes, and sandstone with lava debris are evidence. Although the basal complex is made up of rocks which one would suspect were of marine origin, it is deformed and transformed to such a degree by metamorphism that one cannot unravel its history. Following Salas (1949) geologists speak of the basal complex in the region of Santo Tomas Otlaltepec and Acatlan as the "Acatlan Schist," and this may be the same basal complex as that which occurs in the southwestern part of the Tehuacan Valley. The term "basal complex" is preferred here because it includes numerous rock types rather than schists alone, and because it better indicates our ignorance on the subject. We should recall that the basal complex is visible where erosion has exposed and even strongly attacked it—in the southern part of the Sierra de Acultzingo, in the Sierra Mazateca, and also some twenty kilometers west of Zapotitlan Salinas, in the region of Santo Tomas Otlaltepec.

This part of the Mesozoic is more easily studied in the region under investigation, for it is well exposed in the Sierra de Zapotitlan and in the northern part of the Sierra de Acultzingo, to the east of Cerro Colorado de Tehuacan or Cerro de Los Cuarteles.

In the Sierra de Zapotitlan, the northeast and east boundary of that part of the Mesozoic forms a convex arc facing the town of Tehuacan. It passes through the outskirts of the former hacienda of Cipiapa (near San Bartolo Teontepec) and crosses the highway between Huajuapan de Leon, Oaxaca, and Tehuacan eleven kilometers west of Tehuacan. It next includes the Sierra de Miahuatepec and the Sierra de Atzingo and finally joins the valley of the Rio Hondo, which here forms the boundary between the states of Puebla and Oaxaca, at

* Unless otherwise indicated, towns mentioned in the text are in the state of Puebla.

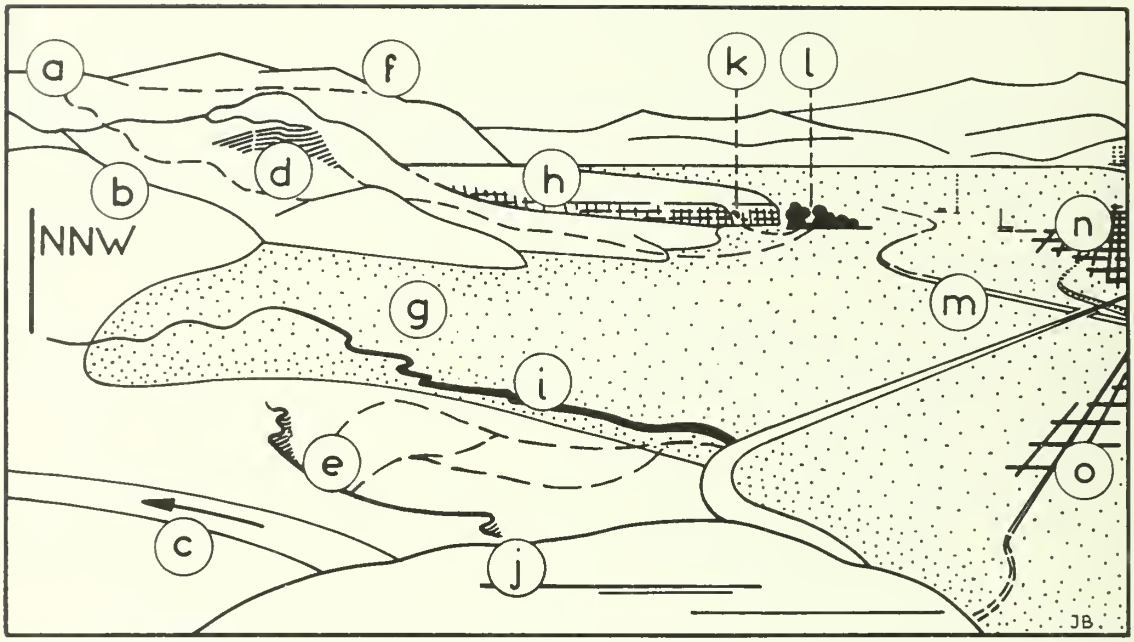


Fig. 27. Cerro de la Mesa and surroundings seen from the Calvario de Coapan, *j*. Other points are: *a*, Sierra de San, Bartolo; *b*, Cuesta del Yeso; *c*, highway between Tehuacan and Huajuapan de Leon, Oaxaca; *d*, *e*, quarries in Cuesta del Yeso; *f*, Sierra de Tecamachalco; *g*, gray soils and other Quarternary deposits; *h*, Cerro de la Mesa plateau; *i*, small gully in Quaternary deposits; *k*, El Riego Cave; *l*, former hacienda El Riego; *m*, canal from Valsequillo Reservoir; *n*, Tehuacan; *o*, Santa María Coapan.

about 18° 10′ N. This topographic boundary corresponds to the end of the Middle Cretaceous and the beginning of the Cenozoic. Although it is thought to be present in the Sierra de Atzingo,* the Upper Cretaceous appears to be absent in this region.

The invertebrate deposits of San Juan Raya, in the interior of the Zapotitlan Valley, have for a long time attracted the attention of geologists and stimulated the study of the Mesozoic strata of the region.

Let us briefly recall the principal facies represented in the Middle and Upper Cenozoic of the region, and their characteristics.

The Jurassic is continental except in the northern part of the region under review. It includes two distinct formations between which the stratigraphic relationships are not clear—the Matzitzi formation, described by Aguilera (1906), to the south of Zapotitlan; and the "Red Beds" in the southern approaches of the Sierra de Santa Rosa. Both consist of sandstones and conglomerates, but the Red Beds in general exhibit a more argillaceous facies than the Matzitzi formation.

The Cretaceous is always clearly marine. In the Lower Cretaceous, or Puebla Group, one finds, in normal stratigraphic order, the Zapotitlan formation, the San Juan Raya formation, and then the Miahuatepec formation.

The Zapotitlan formation, marly on the whole, also includes limestones with rudistids and neritids. It is assigned to the Barremian. Two members are distinguished—the Agua del Cordero and the Agua del Burro. The Zapotitlan formation is found in the entire region surrounding the road from Tehuacan to San Juan Raya, between the outskirts of San Antonio Texcala and the place called Mata Calabaza on the far side of Zapotitlan Salinas.

The San Juan Raya formation, found to the west of the Zapotitlan formation as far as the outskirts of San Nicolas Tepostitlan, is not as extensive as Aguilera (1906) believed. It has been assigned to the Aptien. Its lithology is similar to that of the preceding formation. In the vicinity of the hamlet of San Juan Raya an abun-

* At the foot of the Sierra de Atzingo we collected a sample of calcareous breccia (Lower Cenozoic). Micropaleontological analysis, the results of which were transmitted to us by Dr. Jacques Butterlin, show that one of the elements in this breccia belongs to the Upper Cretaceous. This element surely came from Sierra de Atzingo. An analysis of his sample appears under note 6 below.

Fig. 28. Alternating and folded limestones, marls, and gypsum of the Cuesta del Yeso, km. 7, Tehuacan–Huajuapan de Leon highway.

Fig. 29. Extraction of marly limestone and gypsum from quarry at *e* in Fig. 27.

Fig. 30. Lagoonal sediments exposed in Cerro Agujereado. Coxcatlan Cave lies below the exposed face; the talus of excavation shows the lateral extent of the shelter.

dance of about ten fossil species can be found (Calderón García 1956; 70): *Pterotrigonia plicatocostata* (Nyst and Galeotti), *Tylostoma aguilerai* Alencaster, *Nerinea* sp., *Neithea* sp., *Pyrazus scalariformis* Nagao, *Corbis (Sphaera) corrugata* Sowerby, *Cerithium bustamantii* (Nyst and Galeotti), *Isognomon lamberti* (Müllerried), "*Cyprina*" *sanzi* Landerer, and *Exogyra acuticosta* (Nyst and Galeotti). One also commonly sees ostreids and corals. During one of our trips, a student found a portion of what appears to be a crustacean claw. This specimen is now being studied.

The Miahuatepec formation makes up the Sierra de Miahuatepec and the Sierra de Atzingo. It comprises limestones with black chert and marly beds and displays many folds. Geologists who have studied the region hesitate to assign a precise age to this formation; it is certain that it is intercalated between the preceding formations and the Cenozoic.

In the Sierra de San Bartolo and surrounding heights the Middle Cretaceous—Albian and Cenomanian—is represented by the Cipiapa formation. The name is derived from that of the former hacienda of Cipiapa, near San Bartolo Teontepec. It is presently used in a sense much more restricted than that of Aguilera. The formation is composed of limestones with chert nodules and dolomitized zones. They are rich in fossils—rudistids, foraminifera, algae, and so on—and are reportedly lower Trinity-Albian (Applin 1955, Calderón García 1956) or upper Albian-Cenomanian (Viniegra and López Rubio in Calderón García 1956).

In chronological order, beginning with the Upper Cretaceous and continuing into the Cenozoic, the evolution of the Tehuacan basin was marked by the following essential episodes:

1. Principal orogenic stage and the beginning of the isolation of the future Tehuacan Valley from the Gulf of Mexico.

2. Deposition of lagoonal sediments rich in saline material, in particular fibrous gypsum associated occasionally with "lance-head" gypsum. These lagoonal sediments are well represented in the following regions: Cuesta del Yeso, between the slopes of the Sierra de San Bartolo and the neighborhood of the Sierra de Atzingo; Calvario of Sta. María Coapan; Calvario of San Sebastian Zinacatepec; the vicinity of Coxcatlan; Pueblo Nuevo; San Jose Tilapa; and Teo-

Fig. 31. Cerro Colorado de Tehuacan.

titlan del Camino. They may also be seen along the highway from Tehuacan to Veracruz, between the outskirts of Tehuacan and kilometer 260, close to Chapulco.

An approximately lateral facies consists of the "Red Conglomerates" derived from the extensive erosion of new mountain chains. From them are formed in particular Cerro Colorado of Tehuacan and Cerro Colorado of Ajalpan.

3. New orogenic movements marking the final isolation of the valley from the sea and the close of lagoonal deposition.

4. Formation of a large lake whose sediments, most often consisting of travertines, are well preserved today in the northwest part of the valley—in the vicinity of Tepanco de Lopez, Cerro de la Mesa, the cuestas of San Marcos and Altepexi and also perhaps in the vicinity of the village of Axusco. These sediments are discordant on the preceding ones and show perfect horizontal stratification.

Some fine cuts permit the description given in Fig. 33, which lists the sediments from top to bottom. How can one classify and date these assemblages? The search for macrofossils gave no results, although it had been made earlier, especially during preparations for the Twentieth International Geological Congress in 1956, and by us in the summer of 1964. We therefore collected some samples with the object of searching for microfossils. Analyses of some thin sections, results of which were furnished us by Dr. Jacques Butterlin, gave not the slightest chronological hint (see corresponding notes).

The red conglomerates correspond exactly with those in the northern part of the state of Oaxaca. They belong to the Huajuapan formation and are, at least in part, a lateral facies of the lagoonal-lacustrine sedi-

Fig. 32. Cerro Colorado de Ajalpan and the Calvario of San Sebastian Zinacatepec.

Travertine (notes 7 - 11)	
Alternating marls (12), limestones (13, 14), gypsum, conglomerate (15), some chalcedony nodules	"Red Conglomerates"

Fig. 33. Correlation of Cenozoic lateral facies.

ments mentioned above. These sediments are traditionally termed the Tehuacan formation (Aguilera 1906). However, one could reserve the latter name for the part rich in saline material and in this way reduce still further the extent of the old "Tehuacan formation" of Aguilera.

The remaining lacustrine travertine that is discordant on the saline sediments could then be called the Cerro de la Mesa formation, after Cerro de la Mesa, which rises behind the former hacienda of El Riego. The Cerro de la Mesa formation would therefore represent the end of the continental Cenozoic in the region and perhaps the beginning of the Quaternary. The stratigraphic sequence then becomes as shown in Fig. 35. It is possible that the Tehuacan formation is in part later than the Huajuapan formation. That is, its upper part doubtless corresponds to the Yanhuitlan beds of Salas (1949).

The presence of vertebrate fossils has made it possible to assign an Eocene-Oligocene age to the red conglomerates of the state of Guanajuato (Fries 1955).

Fig. 34. Cerro de la Mesa, viewed from the irrigation canal north of El Riego.

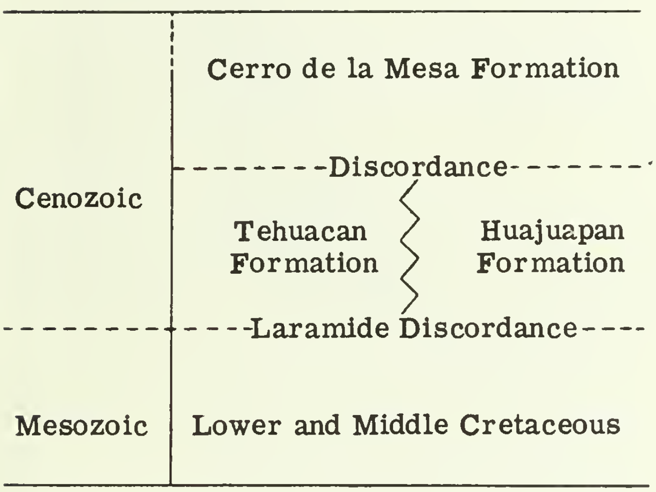


Fig. 35. Correlation of Mesozoic and Cenozoic formations.

One may assign the same age to the Huajuapan and Tehuacan formations (Calderón García 1956). The Cerro de la Mesa formation would be approximately Mio-Pliocene in age.

In order to complete the stratigraphic data on the Cenozoic, it should be pointed out that in the region of Axusco and near Chilac a certain number of strata, whose correlations are not clear, ought definitely to be assigned to the Tehuacan formation, using the term in its restricted sense. These include limestone (notes 16 and 17), sandstones (18), breccias (19), and so on.

Vulcanism was of only limited importance in the Tehuacan region, although it is undoubtedly responsible for a part of the mineralization of the underground waters. Some volcanic units in the valley have been known for some time. These include, for example, the andesites of San Bernardino lagoon near Santa Ana Otzolotepec. A map published by L. Blásquez in 1957 shows a volcano in the region of the San Marcos hills, to the south of the former hydroelectric station No. 2 of Tehuacan, but we have not found anything to correspond with this. On the other hand, between Chilac and Atzingo we did find a volcanic complex (20, 21), the extent of which could not be defined exactly. On the other side of the valley, to the east of Ajalpan, we briefly studied units—lavas, cataclastic rocks (22), and volcanic tuffs (23)—of a volcano that is perhaps fairly important.

There are also some Cenozoic basaltic dikes (24), visible in exposed cuts along the road between Tehuacan and Huajuapan de Leon. One of these is shown in Fig. 36. The cuts were visited by the Twentieth International Geological Congress in 1956.

Formerly volcanic veins were found in the subsoil of the city of Tehuacan at depths of about 80 meters, according to L. Blásquez. It is not possible to determine very much in regard to the age of the majority of these volcanic units, but it is likely that they date from the second half of the Cenozoic.

The end of the Cenozoic is not clearly marked in the Tehuacan Valley, and it is likely that the lacustrine deposits of the Cerro de la Mesa formation extend somewhat into early Quaternary times.

The Formation of the Present Valley

The present characteristics of the Tehuacan Valley, and particularly the fact that it is today a valley and not

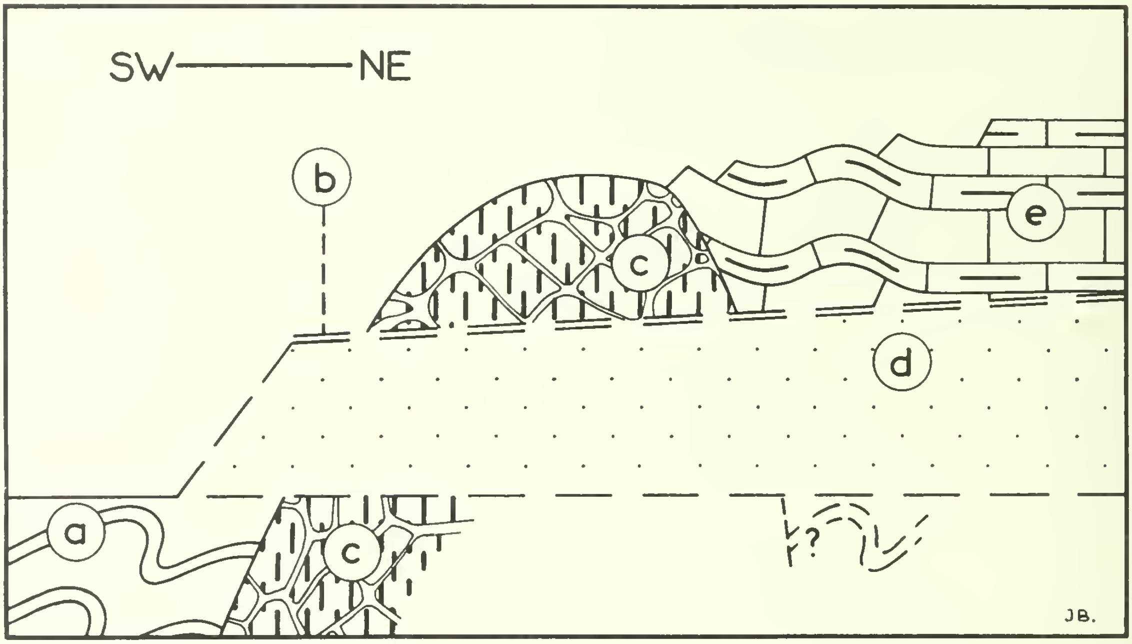


Fig. 36. Basaltic dike exposed at 10.1 km. on the Tehuacan–Huajuapan highway. This dike is possibly more recent than the one cited in note 24. *a*, Rocks of Zapotitlan formation; *b*, *d*, highway and embankment; *c*, basaltic dike with calcitic veins and marks of alteration; *e*, limestones and marls of Tehuacan formation.

an interior basin, can be attributed to an event that probably took place during the early Quaternary. Headward erosion by the Rio Santo Domingo, an affluent of the Rio Papaloapan, resulted in the capture by the Santo Domingo of the lake in which the sediments of the Cerro de la Mesa formation were deposited. This probably occurred near the present site of Quiotepec, Oaxaca.

The old sedimentary basin was approximately bounded by the following points, starting from the north and turning clockwise: Ciudad Serdan, Atzinzintla, the Cumbres de Acultzingo, Santa Maria del Monte, San Pablo Zoquitlan, and Coyomeapan, all in the state of Puebla; then Teopoxco, Concepcion Papalo, Aloapan, San Jeronimo Sosola, Coixtlahuaca, and Jicotlan, in the state of Oaxaca; and finally, once again in the state of Puebla, Acatepec, Atenayuca, Xochitlan, the environs of Tecamachalco, and Quecholac. The lake thus bounded extended on both sides of a line drawn approximately through the following points: San Gabriel Tetzoyocan, San Miguel Zozutla, Tepanco de Lopez, Tehuacan, and the course of the Rio Salado into Oaxaca, thence through Quiotepec and the course of the Rio Grande de Cuicatlan to the region of the canyon of the Tomellin. The slopes of the surrounding mountains were drained by rivers in existence today—Rio Salado, Rio Tehuacan, Rio Hondo, Rio de Parian, Rio Grande de Cuicatlan, and their numerous tributaries. Before the capture of the basin, these streams were shorter, independent of each other, and discharged into the lake.

Such was the hydrography at the time of the capture of the ancient lake. Some interesting comments about this capture can be found in Barrera, who refers to it as "a case of piracy" by the Rio Papaloapan (1946: 24 and fig. 10). He goes on to explain how the headward erosion of the Rio Papaloapan—actually its tributary, the Santo Domingo—connected the old, closed basin with the lower valley of the Papaloapan, thus bringing about the drainage of the waters of the lake.

One must emphasize the extreme importance of this capture to the geomorphological evolution of the region. The old lacustrine system—stable in equilibrium and functioning, one might say, as a closed system—was abruptly transformed into an area of intense erosion. It was an area with two heads, comprising a northwestern sector, drained toward the southeast by the Rio Salado, and a south-southeastern part, drained toward the north-northwest by the Rio Grande de Cuicatlan. Such an arrangement, or "T-shaped drainage," is fairly characteristic of captured drainage patterns (see Fig 37). The lacustrine basin, situated some 1700

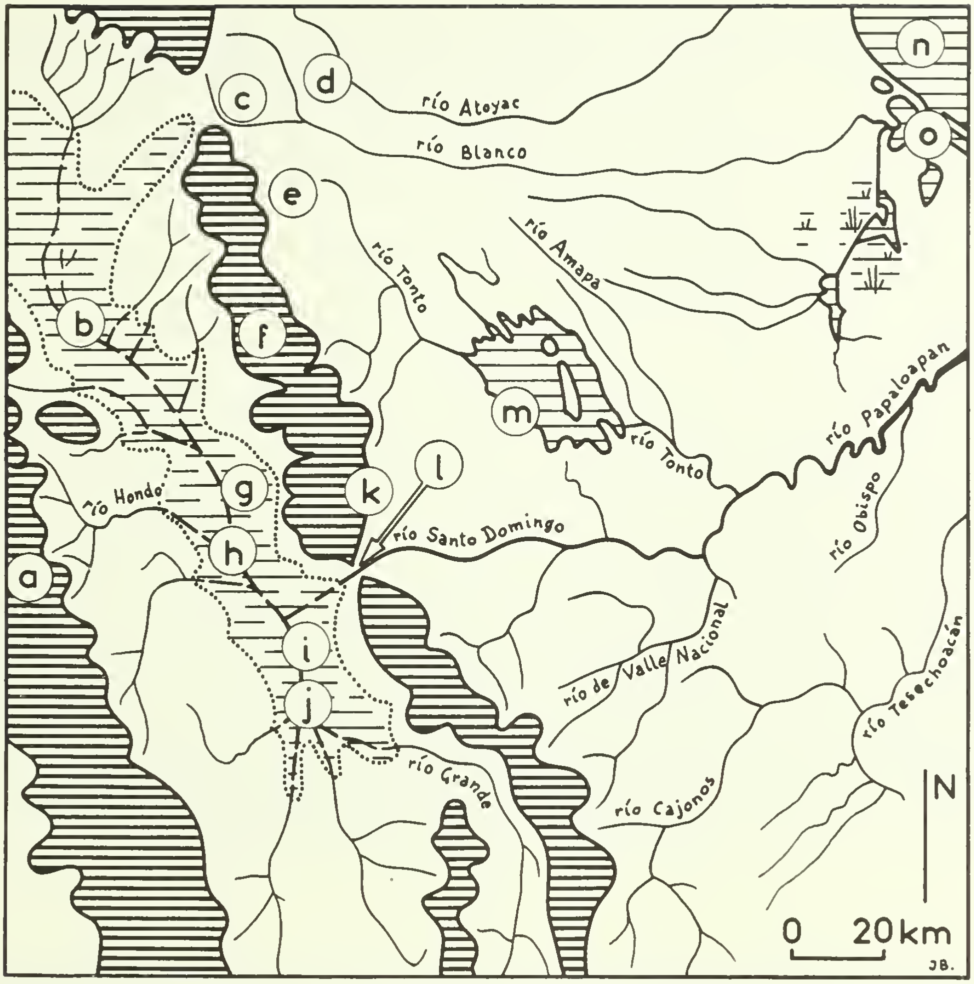


Fig. 37. Capture of the Tehuacan–Cuicatlan basin by a tributary of the Rio Papaloapan. *a*, Sierra de Zapotitlan; *b*, Tehuacan; *c*, Orizaba; *d*, Cordoba; *e*, Zongolica; *f*, Sierra de Zongolica; *g*, Teotitlan del Camino; *h*, extent of former closed lake in Tehuacan-Cuicatlan basin; *i*, Quiotepec; *j*, Cuicatlan; *k*, Huautla de Jimenez; *l*, site of capture of former lake by the Rio Santo Domingo; *m*, Presa Presidente Miguel Alemán; *n*, Gulf of Mexico; *o*, Alvarado, Vera Cruz.

meters above the sea and less than 200 kilometers from it, emptied itself of its watery resources in two complementary processes. First, the lake disappeared, and with it the base-level of the streams that fed it. Then these streams, finding slopes and indices of erosion that are characteristic of torrents, increased the rapidity with which water was drained from the neighboring mountains.

The consequences of all this are marked. Reserves of water in the surrounding mountains have decreased with some delay, but steadily, causing the hydrostatic base-level to sink lower as time passes. We shall discuss this point in detail in the section below dealing with the district of the former hacienda of El Riego. The net result is that the valley becomes drier and even desert-like. Concerning this last point we may make one observation: there is no reason to believe that the climate as a general phenomenon, could have changed much during the last stages of the Quaternary. However, the microclimates of the valley have progressed toward ever more marked aridity because of the disappearance of the water.

Quaternary sediments in the former basin can be classified under three headings:

1. Encrusted material deposited in different parts of the valley by springs rich in minerals—silica, carbonates, nitrates, chlorides, sulfates, and so on. These are found along the edge of the Cerro de la Mesa between

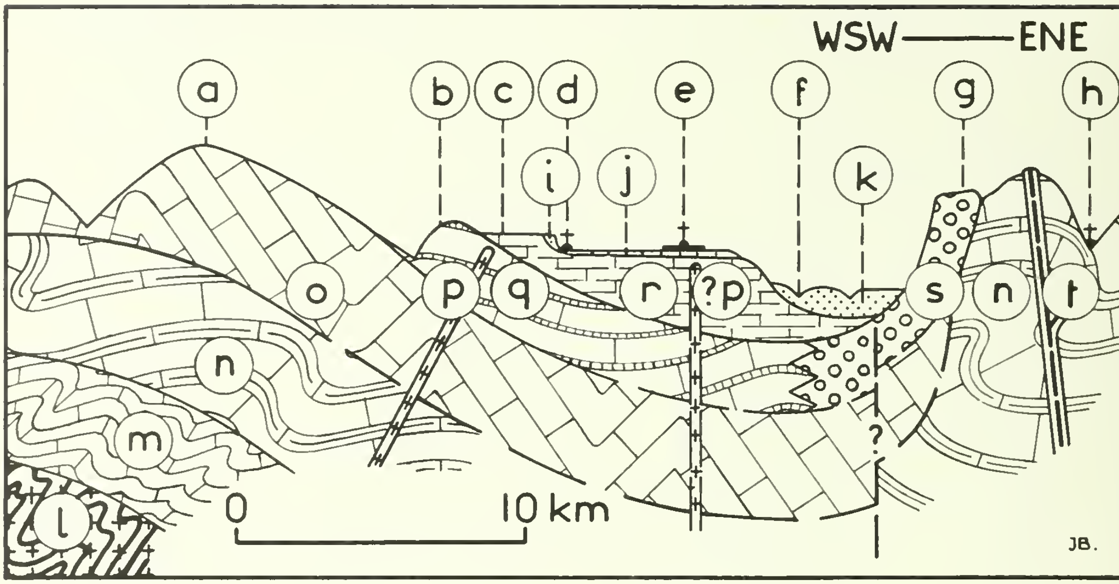


Fig. 38. Section approximately WSW–ENE between Sierra de San Bartolo, *a*, and San Antonio Las Cañadas, *h*. Other points are: *b*, Cuesta del Yeso; *c*, Cerro de la Mesa; *d*, former hacienda El Riego; *e*, Tehuacan; *f*, Rio Salado; *g*, Cerro Colorado de Tehuacan; *i*, encrusted deposits along face of Cerro de la Mesa; *j*, gray soils and other recent deposits; *k*, alluvium; *l*, "basal complex"; *m*, Jurassic levels; *n*, Zapotitlan, San Juan Raya, and similar formations; *o*, Cipiapa formation; *p*, basaltic dike; *q*, Tehuacan formation; *r*, Cerro de la Mesa formations; *s*, "Red Conglomerates" of Huajuapan formation; *t*, andesitic extrusion.

Fig. 39. Encrusted travertine near El Riego.

Fig. 40. Detail of encrusted travertine showing impressions of plants.

San Lorenzo Teotipilco and El Riego. The alignment of the springs or *manantiales* in this region cannot be attributed to a fault, as has sometimes been thought, but to the general direction of the erosion front of the travertine of the Cerro de la Mesa formation. Further deposits of encrusted material are found along the sides of the cuestas of San Marcos and Altepexi, near Cerro Tepetroje (25, 26), and Cerro Pelon (27, 28). Also of interest is a geyser-like spring on the summit of the hill called Petlanco which is depositing chlorites and sulfates, and to whose waters medicinal properties are attributed.

2. Alluvium—clays, sands, gravels—scattered between the environs of San Diego Chalma and the low part of the valley. In the following section we shall see that this alluvium is undergoing a somewhat unusual geomorphological evolution—an "internal filling." This alluvium is often covered with a calcareous crust or "caliche" which greatly reduces its fertility. We probably should not draw any climatic inferences from the presence of this caliche: it simply results from the supersaturation with carbonates of the capillary and circulating waters of a large part of the valley.

3. Slope deposits occur particularly at the foot of Cerro Colorado de Tehuacan, Cerro Colorado de Ajalpan, and the ancient massif formed by the basal complex in the southeastern part of the valley. It appears that these deposits are accumulated at the foot of the Sierra de Zongolica, a circumstance that is explained by the fact that this side of the valley has steeper and drier slopes and erosion is therefore unable to remove the debris that is constantly forming.

Phenomena of "present-day geology" are an interesting study in the Tehuacan Valley, especially in connection with relations between erosion and sedimentation on the one hand and hydrologic equilibria on the other. We will return to this matter in the following section. One could give great importance to karst phenomena in this valley, but we do not believe that they merit being considered the key to geomorphological problems, because, in general, near Tehuacan calcareous zones are altered and then carried away by erosion without undergoing the "evolution in place" that is characteristic of karst phenomena. In particular, clays formed by decalcification are totally lacking in this region.

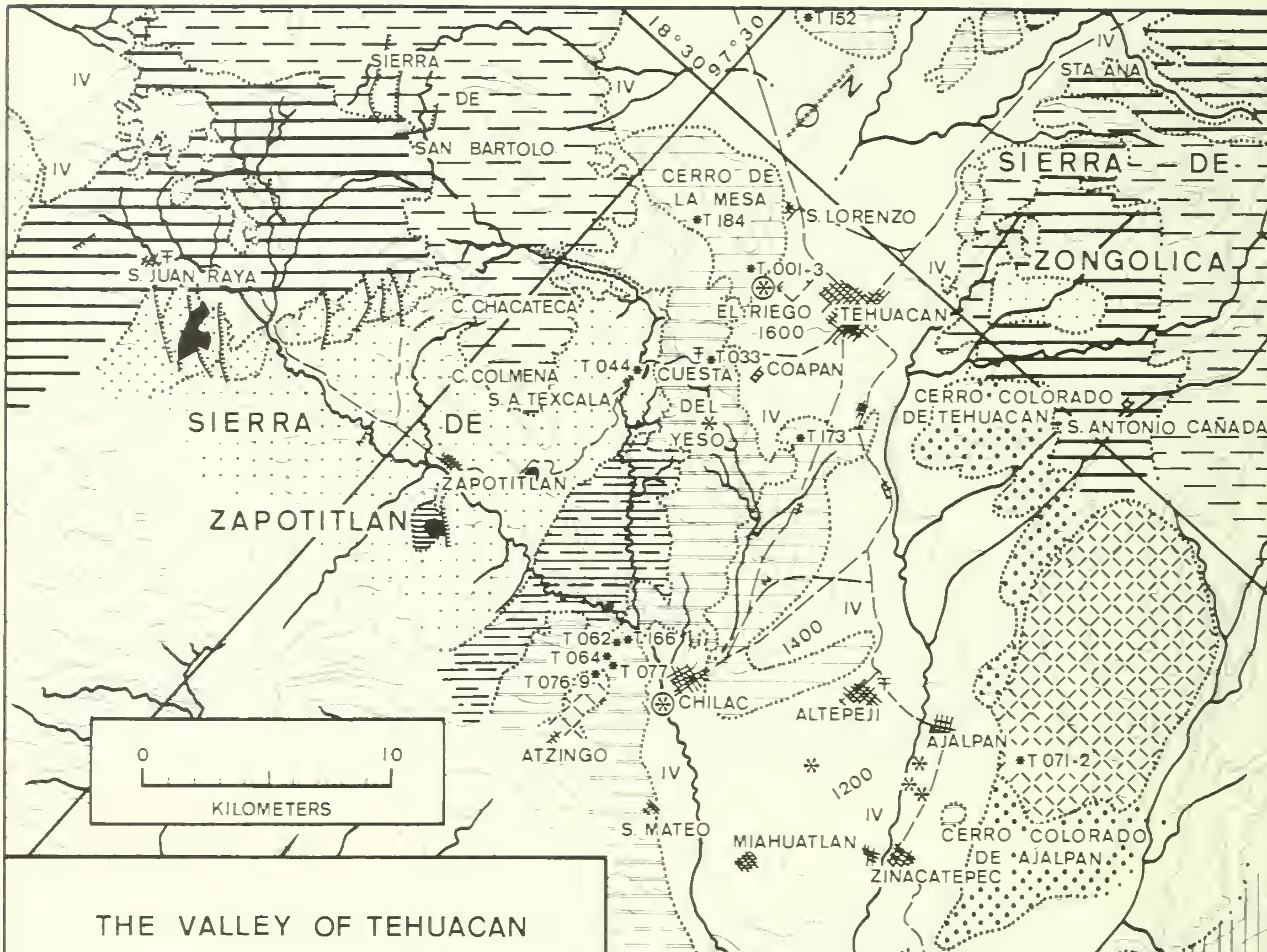


Fig. 41. Tentative geologic map of the Tehuacan Valley.

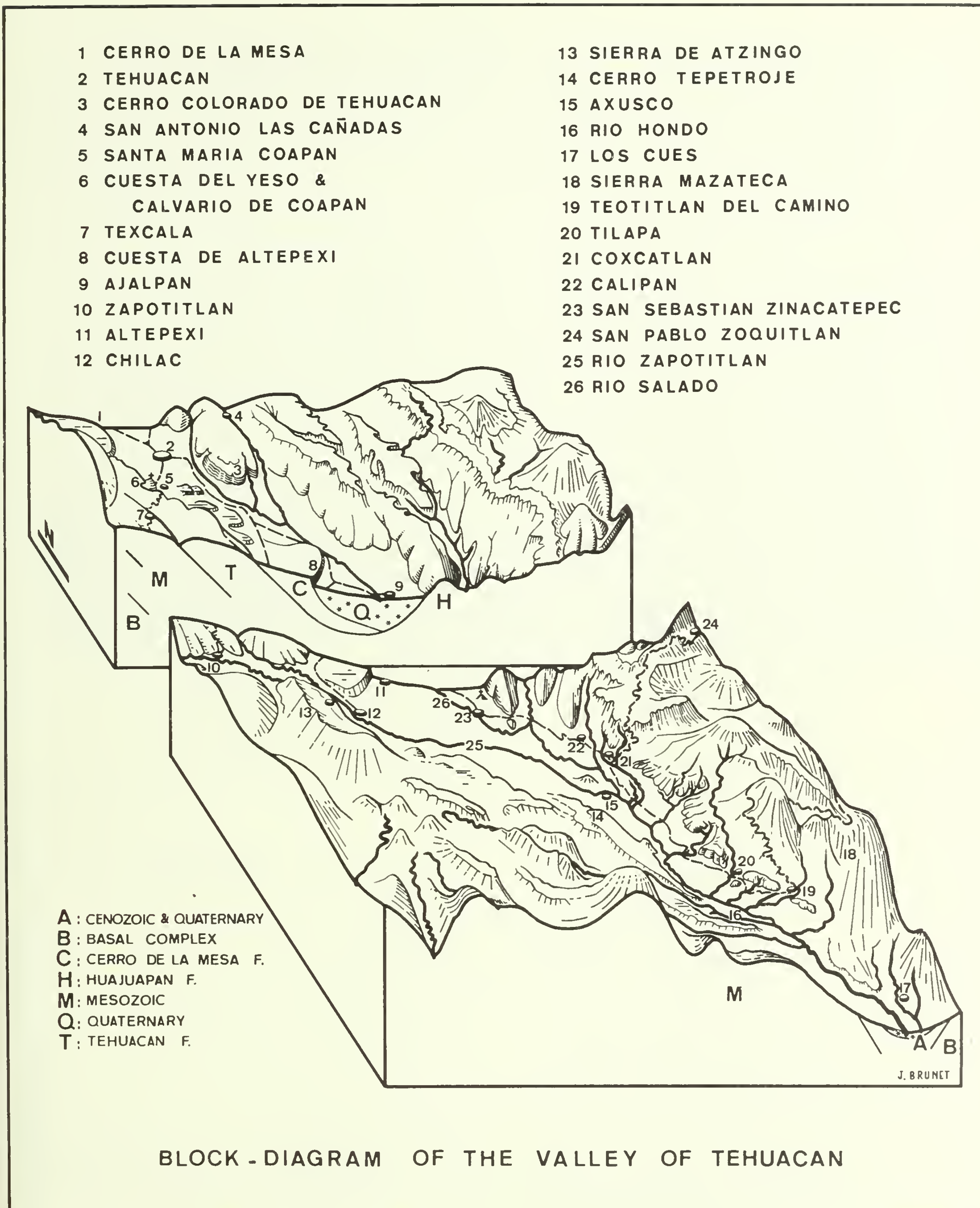


Fig. 42. Block diagram to show relationship of topographic features.

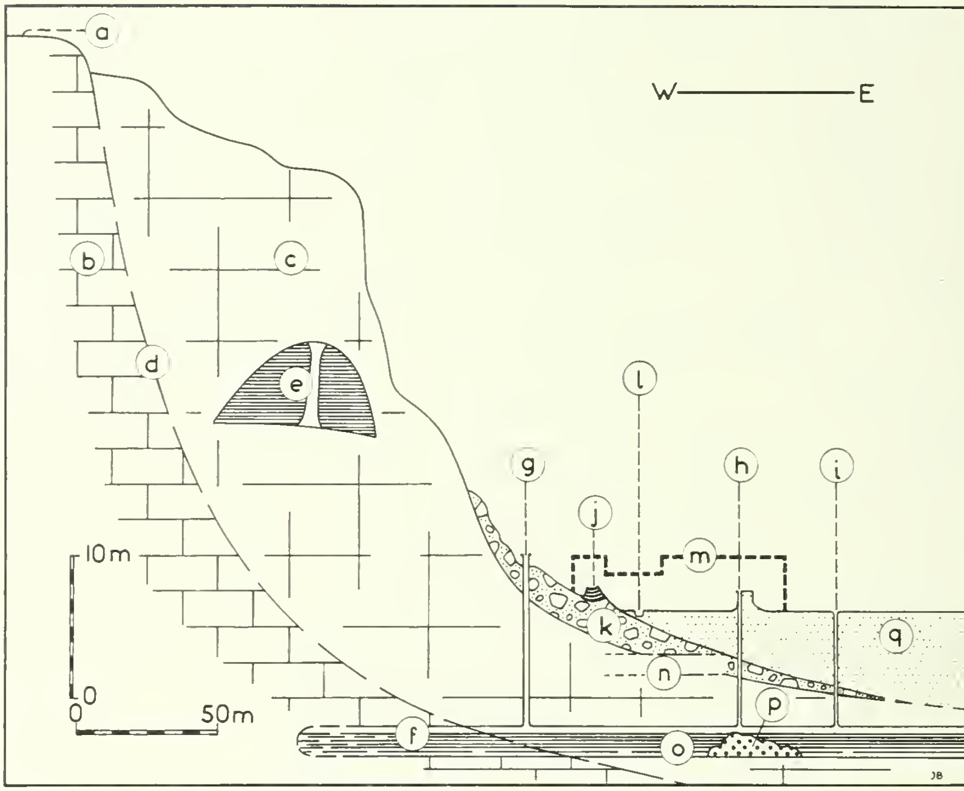


Fig. 43. Section at El Riego Cave, showing geologic and irrigation features: *a*, Cerro de la Mesa plateau; *b*, stratified travertine; *c*, encrusted travertine; *d*, front of erosion at the end of the rejuvenation of this part of the valley; *e*, El Riego Cave; *f*, modern underground water sources; *g*, *h*, *i*, wells of "El Huizache" network; *j*, a prehispanic canal; *k*, mass of fallen rock and earth; *l*, drain running from San Lorenzo sources to a lower part of the valley; *m*, former factory of mineral water; *n*, collapsed subterranean gallery; *o*, modern gallery; *p*, rubbish; *q*, gray soils and other recent deposits.

The Quaternary fauna, we note, includes *Parelephas columbi* Falconer—near San Jeronimo (Aguilera 1906) —*Parelephas columbi* var. *felicis* Freudenberg—between El Riego and the city of Tehuacan (Müllerried 1931)—and some unidentifiable remains of a proboscidian found during the summer of 1964 at the bottom of a well near Altepexi.

Initiation of the program of the Papaloapan Commission of the Secretaria de Recursos Hidraulicos has partly offset the harmful effects of erosion and drought. This program benefits Tecamachalco and Tehuacan with waters of the Rio Atoyac Poblano impounded by the Valsequillo Dam. The valley of the Atoyac has a history that parallels that of the Tehuacan Valley, having been an ancient lake that was captured. The lower portions of the Tehuacan Valley, in turn, benefit from waters gathered in the upper part. But in any event soils are poorly developed, except perhaps in the region of the sugar-cane plantations at Calipan in the lower valley. Soils are, in general, gray soils mixed with gravel from the alluvium.

Volcanic and tectonic activity do not seem to have affected the region during the Quaternary. Only small tectonic readjustments are to be noted in the saline beds of the Cuesta del Yeso; this phenomenon is well exposed along the road from Tehuacan to Huajuapan de Leon between approximately kilometer 5.5 and kilometer 10.5.

Fig. 41 is a generalized map showing the principal geologic structures in the Tehuacan region. In order to make it more readily understandable we insert a block diagram (Fig. 42) prepared from the map and making use of all available topographic and altimetric data. We see there, inserted among the ancient structures belonging to the basal complex and the Mesozoic, lagoonal and lacustrine beds of the continental Cenozoic, fol-

Fig. 44. El Riego Cave. The lush growth along the foot of La Mesa is characteristic, as are the epiphytes growing in the trees and the xerophytic plants on the talus.

lowed by beds that represent the end of the Cenozoic and the Quaternary—travertine, alluvium, slope deposits, and so on.

Hydrological Evolution

Environs of El Riego

The preceding paragraphs have emphasized the important role of the rejuvenation of the valley in accelerating the erosion that revives and dissects the lagoonal and lacustrine structures of the ancient basin of Tehuacan. The lowering of the water table in the valley and in the surrounding mountains is a result of this phenomenon, and it also follows in a precise manner a mathematical law of acceleration.

Good fortune permitted a study of the lowering of the water table as time has gone by, not only in the valley, but on its flanks as well—in the valley thanks to an old well-digger born in San Diego Chalma, who in the course of his seventy years saw the water of flowing springs slowly dry up, to be found thereafter only in wells of greater and greater depth, ranging to 10 or 12 meters. On the valley slopes analysis was possible owing to a series of observations in the immediate vicinity of El Riego rock shelter and near the former hacienda of the same name. These observations will be given below. The curve traced from these observations indicates, in addition, the approximate time during which pre-Hispanic irrigation canals, preserved by a calcareous travertine coating, were in use. We were also able to determine the sequence in which a certain number of canals were used.

The cross section (Fig. 43) represents from west to east and from top to bottom the following features: the El Riego rock shelter 22.5 meters above the present water table; a certain number of old springs, traces of which are preserved by encrusted travertine; pre-Hispanic canals "fossilized" by the same travertine; some shallow, collapsed subterranean galleries; and finally, modern galleries about 10 meters deep, used to conduct water obtained from underground sources to the surface. One of these galleries today supplies mineral water to the El Riego bottling plant. Although the method of constructing the older galleries is similar to that used for modern "filtering" galleries, in the older galleries

Fig. 45. The subterranean gallery noted at *n* in Fig. 43.

we are dealing with structures intended to carry water from the foot of the mountain to lower parts of the valley and not gather filtered water along the way. It is for this reason that we speak of underground galleries; they are veritable underground aqueducts.

In the same order, here are the corresponding chronological data. About 7000 years ago a veritable waterfall left travertine deposits in El Riego Cave, a shelter that must have remained very damp up to some 4000 years ago. Various old texts speak of "trenches" built for irrigation at the time of the Conquest or somewhat later, a word that suggests an open ditch with a depth of about a meter. At the beginning of the twentieth century, the water galleries were at a depth of "a few meters," according to the master well-digger to whom we have referred. These are the abandoned subterranean galleries with depths of three to five meters previously mentioned.

In order to define precisely the age of the "modern" galleries, we note that a network called "El Huizache" was dug in 1964. In this porous limestone region the presence of water (hydric level) is closely related to the upper limit of the "zone of cementation" (hydrostatic level). The curve shown in Fig. 46 confirms that the successively higher levels at which water was obtained represent levels of increasingly greater age. This makes it possible to date pre-Hispanic canals with a wholly relative precision. Those radiating from El Riego were in use between A.D. 1000 and the Spanish conquest and had maximum use about 1200. This dating applies only to canals and galleries, both "fossil" and modern, that radiate directly from El Riego. Other irrigation systems, originating at San Lorenzo Teotipilco, cross the district around El Riego and run about ten meters above the galleries we have discussed.

It follows from these remarks that when one is studying a fascicle of canals—a fan-shaped assemblage originating from a single spring—the oldest are the highest, and inversely, those at the lowest level are the most recent. The same "geochronological" method could be applied with fruitful results to the regions of the cuestas of San Marcos and Altepexi.

The Vicinity of Ajalpan

One may say that erosion progresses by moving up the drainage basin. In the Tehuacan Valley this means that shortly after the capture of the basin by the Rio Papaloapan system, erosion was very active in the lower parts of the valley, around San Juan de los Cues and in the vicinity of Teotitlan del Camino. Later erosion affected more strongly the regions around the towns of Venta Salada and Coxcatlan, then Ajalpan and Chilac. Today the strongest evidence of erosion is seen in the vicinity of Tehuacan, especially in the zone of the "Red Conglomerates"—Cerro Colorado de Tehuacan. One notes there the presence of multiple gullies, or cañadas—la Cañada de San Antonio, for instance. To the north, in the vicinity of Tepanco de Lopez, erosion is weaker, but one may predict its extension in the future.

The predominantly sedimentary material torn from regions strongly attacked by erosive activity is not necessarily carried as far as the lower basin of the Rio Papaloapan, nor for that matter into the waters of the Gulf of Mexico. After being carried a relatively short distance, it is dropped in the intermediate sections of the valley. For several thousand years such deposition has been most actively building up in the region around Ajalpan. Thus the intermediate valley is filled in proportion to the rate of erosion in the upper reaches. It is clear that in turn this filling of the intermediate valley is attacked by erosion and is extensively gullied—a phenomenon clearly seen in the immediate outskirts of Ajalpan.

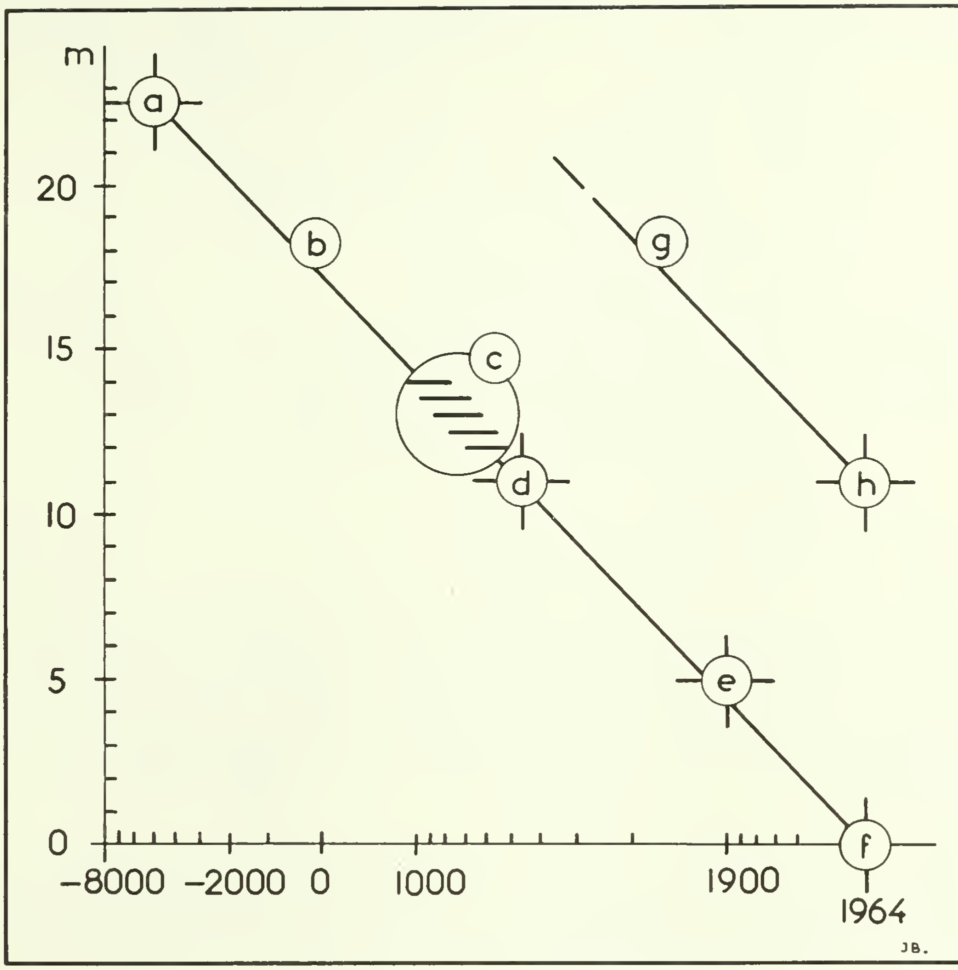


Fig. 46. Diagram to date prehispanic canals, *c*, in the vicinity of El Riego Cave, *a*. Water levels in meters on arithmetic scale; time between 8000 B.C. and A.D. 1964 expressed in logarithmic scale. *b*, function expressing correlation between water table and time; *d*, trenches built for irrigation about 1519; *e*, old collapsed galleries; *f*, modern galleries; *g*, hypothetical function for the abandoned canal from San Lorenzo, passing east of El Riego; *h*, actual situation of this drain.

When it is difficult, then, to divorce erosion and sedimentation, it becomes possible to understand the phenomenon in its entirety. The disequilibrium created by the capture of the ancient basin by a tributary of the Rio Papaloapan set in motion a complex phenomenon affecting the evolution of relief. This is expressed by a shift of erosive activity toward the northwestern part of the valley. After erosion has cleared part of the valley, it is succeeded by sedimentation that fills that part of the valley already cleared. The very intensity of this sedimentation brings about a new disequilibrium of the system, and a new phase of erosion is initiated.

Neither the term "alluvial cone" nor "terrace" is well suited to describe the land built up around Ajalpan. One might propose the expression "intermediate alluviation," or "intermediate filling," or "successive alluviation." If this intermediate filling began in the Pleistocene—the finding in a well near Altepexi of fragments of bone from an extinct proboscidian probably dating from the upper Pleistocene suggests that it did indeed begin then—it has developed fully in the region about Ajalpan during relatively recent times. If we take into account the stratified deposit of numerous archaeological remains in the sediments, the filling of the area must have involved a period of some thousands of years. The sediments consist primarily of clays and gravels, which also are more or less finely stratified. It is obvious that the archaeological evidence falls into

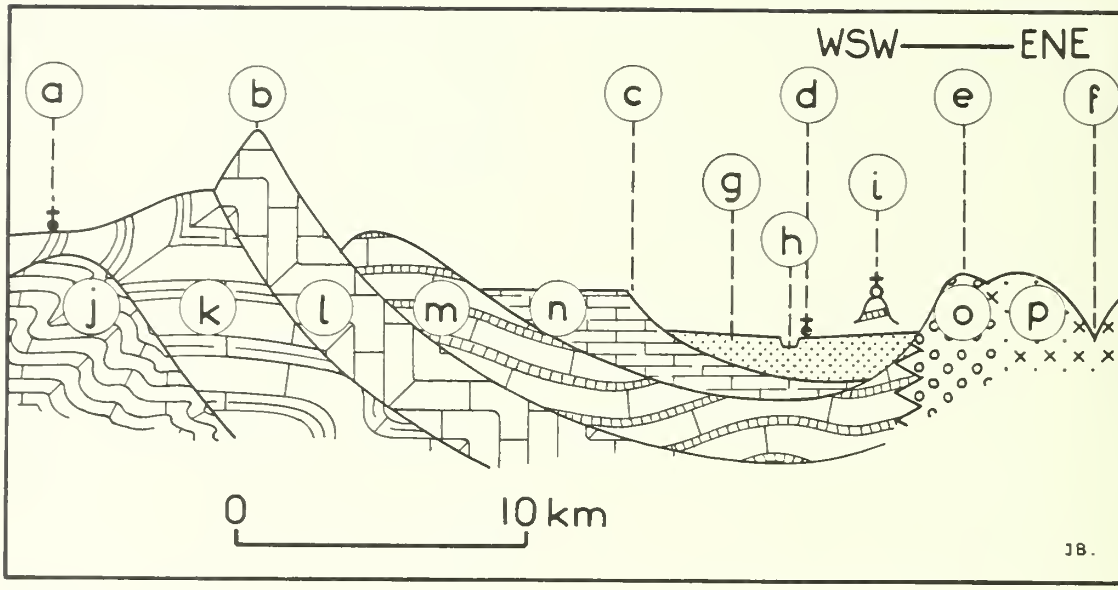


Fig. 47. Section across the Tehuacan Valley through Zapotitlan Salinas, *a*, and Ajalpan, *d*. Other points are: *b*, Sierra de Miahuatepec; *c*, Cuesta de Altepexi; *e*, Cerro Colorado de Ajalpan; *f*, Rio Comulco; *g*, "intermediate filling" of Ajalpan area; *h*, Rio Salado; *i*, Calvario de Zinacatepec; *j*, Jurassic levels; *k*, Zapotitlan formation; *l*, Miahuatepec formation; *m*, Tehuacan formation; *n*, Cerro de la Mesa formation; *o*, Huajuapan formation; *p*, igneous rocks.

a chronological succession in the order in which the specimens appear in the stratigraphic cut under review, the deepest objects being the oldest. One must except burials made in graves dug during periods of temporary dryness in one zone or another, a situation in which dating can only be done by determining the level of the mouth of a grave shaft.

The same remarks apply to the Rio Zapotitlan. The archaeologically interesting zone of intermediate alluviation extends southwestward of the village of Chilac. Some remains occurred in an exposure along the bank of the Rio Zapotitlan exactly one kilometer south of the village square where a human mandible associated with two bone points and some sherds of pottery came to light. These remains date from approximately the beginning of the present era.

It is now possible to pick out some terraces in the immediate outskirts of Chilac. It is very easy to identify them in the arroyo of San Marcos, where three terraces can be separated on morphological grounds and dated by means of their archaeological content.

Mequitongo: The Pre-Hispanic Dams

The dams of Mequitongo, near San Jose Tilapa, are in the Arroyo Lencho Diego between the highway from Tehuacan to Teotitlan del Camino and the rock shelters called Purron and Abejas. The dams were built in a geological environment characterized mostly by Lower Cenozoic continental gypsiferous beds of quite regularly alternating sandstone, marl, marly limestone, and fibrous gypsum—all rocks that are quite easily worked and that were used for building the dams and adjoining structures. The bottom of the ancient impounded lake, now almost invisible because of alluvium, was without doubt formed by the ancient terraces of the stream system that cut the Arroyo Lencho Diego. The collection basin took form in the extreme southern part of the Sierra de Atzingo (Cerro Chichiltepec; Lower—and Middle?—Cretaceous and basal complex).

As for the dams themselves, and without wishing to infringe on the domain of our colleagues Neeley and Woodbury, we would like to propose here some ideas that set forth a method or "geological procedure" for the study of ancient artificial dams. We here consider as artificial dams all those more-or-less massive, man-made structures intended to retain, at least temporarily, an appreciable body of water, and, by the same token, the modification of the natural relief to the extent that it may be necessary for the fulfillment of this end.

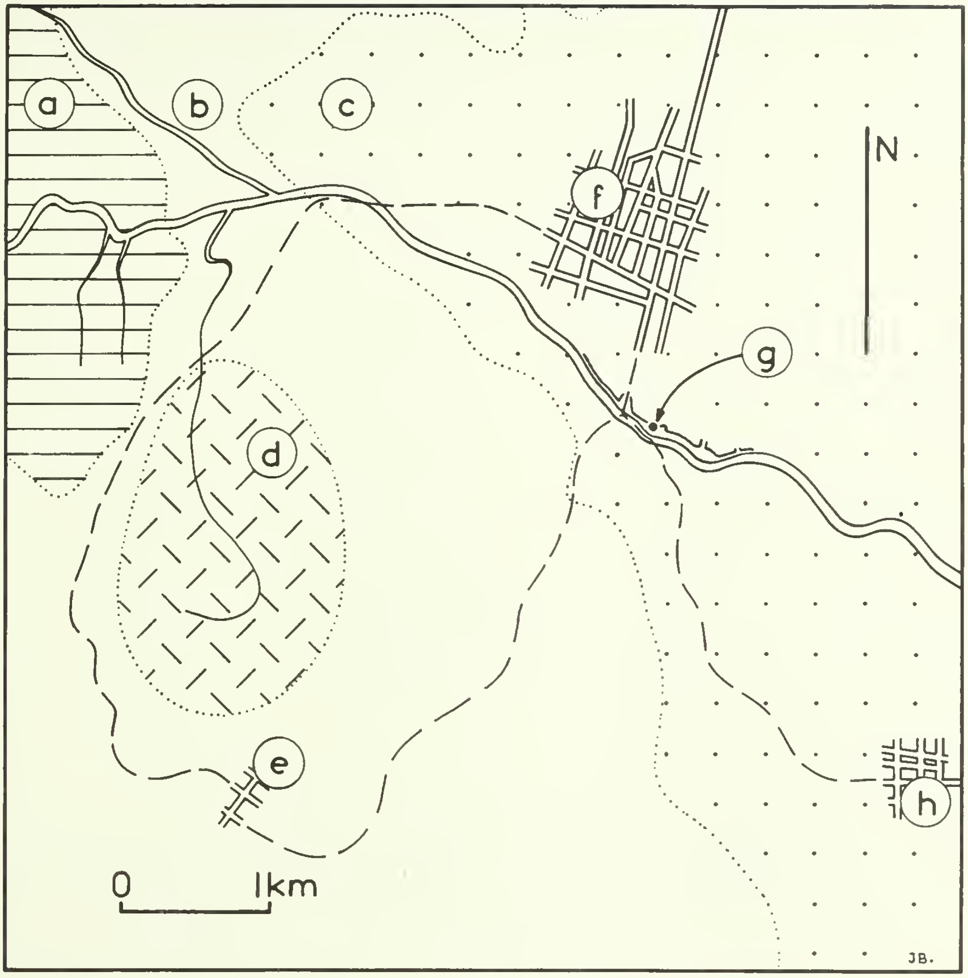
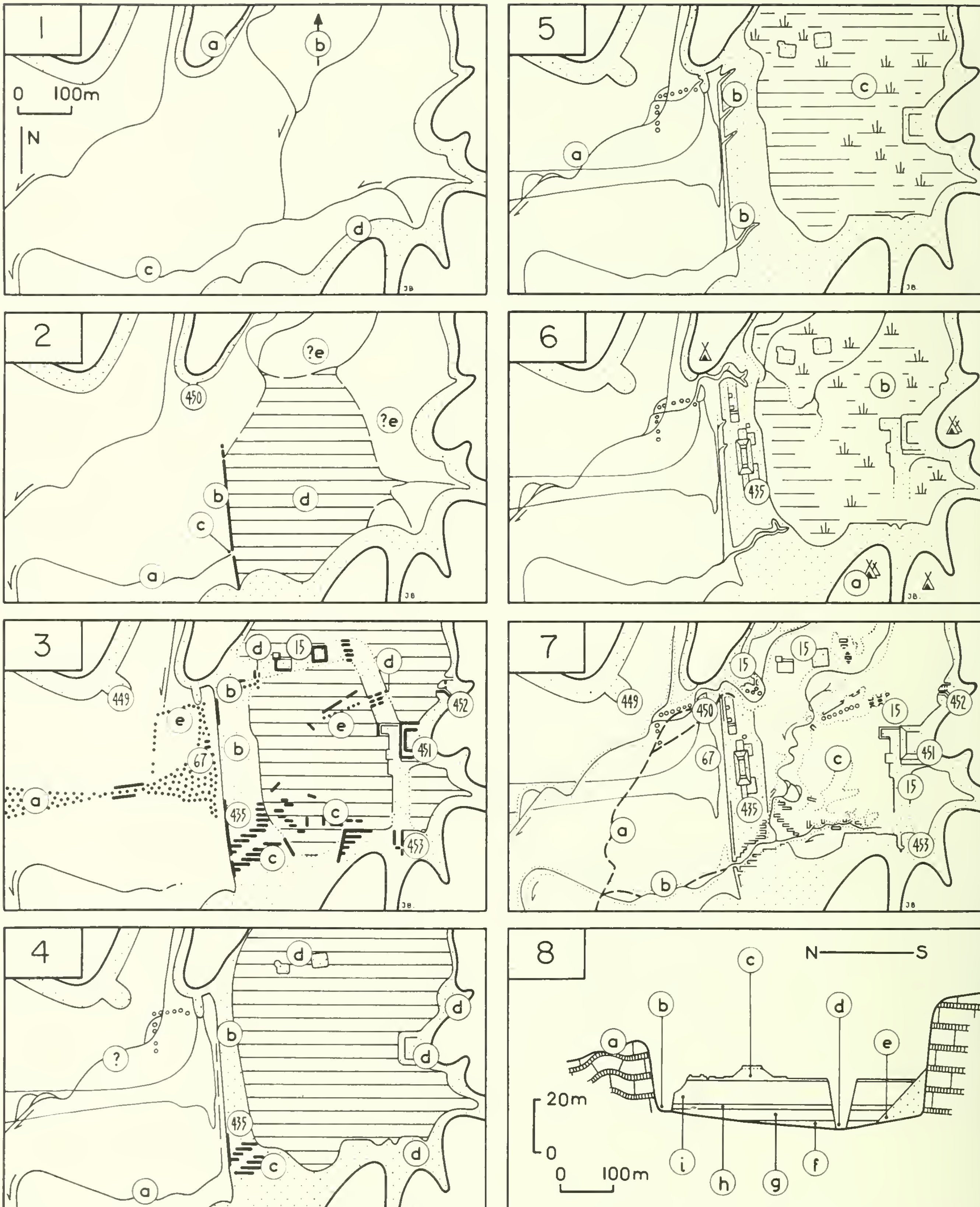


Fig. 48. Chilac and surroundings: *a*, Miahuatepec formation; *b*, Tehuacan formation; *c*, Quaternary deposits; *d*, igneous rocks; *e*, San Juan Atzingo; *f*, San Gabriel Chilac; *g*, human mandible found April 1964; *h*, San Mateo Tlacoxcalco.

Some basic principles must be admitted, in particular the following: the pool above a dam begins to fill with sediments practically from the moment of its construction. Consequently, in the case of superposed dams, alluvial deposits that correspond horizontally with each stage of the structure are each contemporaneous with the stage to which they correspond. In effect, if the construction of a dam requires one or several years, the length of time required for the sedimentation of the basin will be measured in the majority of cases in some tens of years. This is especially true where erosion is very active, as in most of the valleys of the Mexican plateau and connected regions, such as the Sierra Madre de Oaxaca and the Sierra Madre del Sur. Geologically and even archaeologically speaking, such intervals usually elude our analysis and may be considered to be units too small to measure in the past history of any given region. This premise makes it much easier to interpret past events, for it allows us to consider the mass of a dam as a lateral facies of its own alluvium and vice versa. Another principle is this: the total capacity of the pool impounded by a stage in the construction of a dam is represented by the corresponding body of alluvium.

Finally, the localization of zones of heaviest deposition of gravel has no connection with such concepts as upstream and downstream, at least in the operation and scope of a dam, but depends primarily on water turbulence. Indeed, gravels accumulate where the flow is forced into a confining passage, as in sluice-gates, arches of bridges, narrow canals, and so forth.

We hope that these concepts, already discussed in the field with the project archaeologists, may have helped in their reconstruction of the history of Mequi-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tongo. Here, briefly, is my own interpretation of that history: (1) natural primitive situation, (2) first dam and contemporary structures, (3) second and third dams (separated by a mud flow), (4) fourth dam, (5) abandonment of the region, (6) return of people during Postclassic time, (7) present situation. This interpretation is illustrated in Fig. 49.

In the long geological history of the Tehuacan Valley, the most significant event is the capture of the old, closed Tehuacan-Cuicatlan basin (La Cañada Poblana-Oaxaqueña) by the Rio Santo Domingo, a capture that set in train the loss of the aqueous reserves of the region and completely changed its appearance. The valley, which became drier and drier, nevertheless allowed man to establish himself there, to adapt himself progressively until he was able to take advantage of its scant water resources, thanks to his ingenuity. It is a paradox that this same aridity has preserved for archaeologists the details of the vanquished civilizations of the Tehuacan Valley. Without it, we would never have been aware of them.

Notes on Hand Samples

1. *Specimen T083, section no. 451.* By A. Sotomayor. *Field notes:* sandstone; road from Coxcatlan to Zoquitlan (23 km. from the former, 5 km. from the latter). *Macroscopic description:* clastic rock with light gray color. *Texture:* clastic psammitic. *Detrital components:* quartz, feldspars, calcite, micas. *Cement:* calcite. *Classification:* calcareous sandstone. *Comments:* the rock shows evidence of dynamic metamorphism.
2. *Specimen T087, section no. 452.* By A. Sotomayor. *Field notes:* sandstone; road from Coxcatlan to Zoquitlan (18 km. from the former, 10 km. from the latter). *Macroscopic description:* clastic rock, friable, rose color. *Texture:* clastic psammitic. *Detrital components:* quartz, silicified material, feldspars, some ferromagnesian minerals. *Cement:* kaolinitic clays, chlorite, oxides. *Classification:* quartz sandstone contaminated by volcanic material. *Comments:* the rock is not fully developed.
3. *Specimen T092, section no. 453.* By A. Sotomayor. *Field notes:* sandstone; road from Coxcatlan to Zoquitlan (11 km. from the former, 17 km. from the latter). *Macroscopic description:* white, coffee, and black color. *Texture:* granoblastic throughout. *Minerals:* quartz, hematite, chlorite, limonite. *Classification:* quartzite. *Origin:* metamorphic rock.
4. *Specimen T094, section no. 454.* By A. Sotomayor. *Field notes:* chlorite schist; road from Coxcatlan to Zoquitlan (8.5 km. from the former, 19.5 km. from the latter). *Macroscopic description:* gray and reddish brown color, foliated. *Texture:* granoblastic in zones. *Minerals:* quartz, magnetite, hematite, chlorite, sericite, limonite, graphite. *Classification:* zoned quartz-

Fig. 49. Dams of Mequitongo.

1. Natural situation: *a,* Cerro Lencho Diego; *b,* to Purron and Abejas caves; *c,* Arroyo Lencho Diego; *d,* talus slope.
2. First dam: *a,* Arroyo Lencho Diego; *b,* dam; *c,* probable sluice gate; *d,* impounded lake; *e,* hypothetical monuments preceding accessory dam of next period; *No. 450,* monument.
3. Second and third dams: *No. 435,* principal dam; *No. 15,* accessory dam and associated monuments; *No. 67,* monument probably near important sluice gate; *Nos. 449–453,* contemporary monuments; *a,* gravels deposited in irrigation canals; *b,* probable sluice gates; *c,* wells or heaps of stones exposed by erosion; *d,* flood gates, probably spanned by wooden bridges, connecting the two basins separated by dam No. 15; *e,* gravels deposited by turbulent water of flood gate or drain.
4. Fourth dam: *No. 435,* principal dam; *a,* Arroyo Lencho Diego; *b,* sluice gate; *c,* wells exposed by erosion; *d,* structures of preceding period become islands or peninsulas in water behind dam.
5. Abandonment in Classic period: *a,* present streams established; *b,* natural drains of the dam; *c,* remaining bog.
6. Rebuilding in Postclassic period: *No. 435,* pyramids and parvis built on former dam; *a,* encampment; *b,* bog, or possibly a cultivated zone.
7. Present situation: *No. 435,* four superimposed dams with later pyramids and parvis; *a,* cart track; *b,* Arroyo Lencho Diego; *c,* superimposed alluviums dissected by erosion; *Nos. 15, 67, 449–453,* well-preserved structures.
8. Schematic section through the dams: *a,* Cerro Lencho Diego; *b, d,* eroded gullies; *c,* Postclassic buildings; *e,* talus; *f, g, h, i,* superimposed dams.

Fig. 50. Dams at Mequitongo: canal or sluice gate exposed in bank of arroyo at left-hand structure No. 15 in Fig. 49, 7. Gravel fill at bottom is clearly discernible.

ite. *Origin:* metamorphic rock, formed from a sedimentary rock.

5. *Specimen T099, section no. 455.* By A. Sotomayor. *Field notes:* marble; road from Coxcatlan to Zoquitlan (5.5 km. from the former, 22.5 km. from the latter). *Macroscopic description:* massive rock, compact, light green color. *Texture:* granoblastic. *Minerals:* calcite, quartz, amphiboles. *Classification:* marble. *Origin:* metamorphic rock.
6. *Specimen T064, section no. 64–2332.* By Dr. Federico Bonet and Enrique Riva Palacio. *Field notes:* calcareous breccia; barranca on first stream met after crossing the Rio Zapotitlan (or Rio Chilac) on the road from Chilac to Atzingo. *Description:* red calcareous breccia; consisting of a matrix of silicified limestone with abundant iron oxides and foraminifera remains. This matrix encloses the following constituents (up to 4 cm. in diameter): (*a*) limestone with foraminifera, small amounts of microcrystalline material and many globigerina chambers; (*b*) microcrystalline limestone, fine-grained, with recrystallized micro-veins, considerable iron oxides, and rare foraminifera fragments; (*c*) medium-grained, microcrystalline limestone with granoblastic texture; without fauna; (*d*) fine-grained, microcrystalline limestone with numerous thin, recrystallized veinlets, feldspars, iron oxides; numerous chambers of globigerina and other foraminifera, in particular a well-conserved specimen of *Rotalipora* sp. and also *P. trejoi* and *Calcisphaerula innominata. Comments:* the presence of these fossils allows one to assign an Upper Cretaceous age only to the fragments that contain them, while the breccia itself may be of a later age. The appearance of the rock suggests the continental "red conglomerates" of the Lower Cenozoic that are very common in many areas of Mexico.
7. *Specimen T001, section no. 64–2324.* By Dr. Federico Bonet and Enrique Riva Palacio. *Field notes:* horizontal beds of travertine; Cerro de la Mesa, 200 m. west of El Riego spring, near Tehuacan. *Description:* cream-coffee-colored marly limestone, partially recrystallized and extremely silicified. In spite of diagenesis there are biogenic remains that probably correspond to mollusks, bryozoans, and algae; lacking characteristic fauna.
8. *Specimen T003, section no. 64–2325.* By Dr. Federico Bonet and Enrique Riva Palacio. *Field notes:* horizontal beds of travertine; Cerro de la Mesa, 200 m. west of El Riego spring. *Description:* fine-grained, argillaceous, pseudo-colitic limestone of light-coffee color; matrix contains small amounts of finely microcrystalline limestone, with clastic constituents (small and medium-sized) of quartz, potassic, and sodic feldspars, subangular and irregular; parts filled with granoblastic spathic calcite and rare mica flakes; the major part of the pseudo-colites are partially silicified. Some mollusk remains, a poorly preserved specimen of *Globochaete alpina* (?), and other biogenic remains too poorly preserved to be identified.
9. *Specimen T184, section no. 460.* By A. Sotomayor. *Field notes:* travertine, Cerro de la Mesa, 3 km. west of El Riego spring. *Macroscopic description:* coffee-colored and dark gray rock, with zonation. *Texture:* cryptocrystalline. *Constituents:* calcite, clays, phosphates; silicified zones (with chalcedony, quartz, and opal). *Classification:* limestone with silicified zones. *Origin:* sedimentary rock.
10. *Specimen T152, section no. 458.* By A. Sotomayor. *Field notes:* lacustrine limestone; road from Puebla to Tehuacan, near Tepanco de Lopez. *Macroscopic description:* red-colored rock with veins of hematite and calcite. *Texture:* crystalline granular. *Minerals:* calcite, secondary calcite, hematite, quartz, feldspars, limonite, clays. *Classification:* limestone. *Origin:* sedimentary rock.
11. *Specimen T173, section no. 64–2340.* By Dr. Federico Bonet and Enrique Riva Palacio. *Field notes:* lacus-

Fig. 51. Dams at Mequitongo: top of dam can be seen at right but is hidden in brush at left. The truck is at the end of dam near No. 450 in Fig. 49, 7.

trine limestone; San Marcos hill, about 5 km. south of Tehuacan (6 km. on the old direct Tehuacan-Chilac road). *Description:* coffee-colored, medium-grained, microcrystalline limestone, slightly argillaceous with irregular grains of finer, microcrystalline limestone; lacking fauna.

12. *Specimen T033, section no. 64-2326.* By Dr. Federico Bonet and Enrique Riva Palacio. *Field notes:* marl, continental Lower Cenozoic; cut located at km. 8 on the Tehuacan-Huajuapan de Leon road. *Description:* calcareous marl, coffee-ocher color, with very small, irregular, and subangular clastic quartz fragments, and with numerous calcite grains, some of which are rhombohedral; iron oxides. Lacking in microfauna.
13. *Specimen T116, section no. 64-2339.* By Dr. Federico Bonet and Enrique Riva Palacio. *Field notes:* limestone; road from San Gabriel Chilac to San Juan Atzingo, 100 m. after crossing Rio Zapotitlan (Chilac). *Description:* medium- or fine-grained, grayish-green microcrystalline limestone, slightly argillaceous, with finely granular iron oxides. Calcified mollusk and ostracod remains. Lacks characteristic microfauna.
14. *Specimen T153, section no. 64-2337.* By Dr. Federico Bonet and Enrique Riva Palacio. *Field notes:* limestone, 2 km. south of Tehuacan, foot of Cerro Colorado (Tehuacan viejo) at the level of the terraces of Rio Salado. Perhaps of more recent age than T033 and T166. *Description:* coffee-colored, fine-grained microcrystalline limestone, with veins full of spathic crystalline calcite, slightly argillaceous. Numerous calcified radiolaria: *Globigerina* sp. and *Nodosaria* sp. Lacks characteristic microfauna.
15. *Specimen T039, section no. 64-2327.* By Dr. Federico Bonet and Enrique Riva Palacio. *Field notes:* recrystallized conglomeritic limestone; cut located at km. 8 on Tehuacan-Huajuapan de Leon road. *Description:* medium- and fine-grained gray microcrystalline limestone, slightly argillaceous, with iron oxides; certain parts are strongly recrystallized. Remains of mollusks, echinoderms, few ostracods, recrystallized algae. Lacks characteristic microfauna.
16. *Specimen T140, section no. 64-2335.* By Dr. Federico Bonet and Enrique Riva Palacio. *Field notes:* limestone, 1 km. southwest of Axusco, at summit of first hills in front of Cerro Tepetroje. *Description:* coffee-

colored, fine-grained microcrystalline limestone, with geodes lined with calcite, slightly granular, slightly argillaceous. Lacks characteristic microfauna.

17. *Specimen T077, section no. 449*. By A. Sotomayor. *Field notes:* limestone with altered constituents; barranca on first stream beyond Rio Zapotitlan (Chilac) on road from Chilac to Atzingo. *Texture:* clastic. *Constituents:* clastics, calcareous fragments of organisms, remains of microfossils, calcite, oxides, microcrystalline and cryptocrystalline secondary quartz. *Classification:* silicified "calci-rudite."
18. *Specimen T062, section no. 445*. By A. Sotomayor. *Field notes:* sandstone, 200 m. beyond the Rio Zapotitlan (Chilac) on road from Chilac to Atzingo. *Macroscopic and texture description:* clastic psammitic rock. *Constituents:* detrital components (basalt, quartz sandstone, calcite, feldspars, quartz) and cement (calcite, chlorite). *Secondary minerals:* limonite, chlorite. *Classification:* "Lithic" sandstone.
19. *Specimen T137, section no. 64–2334*. By Dr. Federico Bonet and Enrique Riva Palacio. *Field notes:* calcareous breccia; slopes of Cerro Tepetroje about 3 km. southwest of Axusco. *Description:* contemporaneous breccia, with subangular fragments (diameters up to 4 cm.) of coffee-colored, fine-grained microcrystalline limestone, with abundant recrystallized veins, iron oxides, and a little secondary silica, infrequent mollusk remains, calcified radiolaria, foraminifera so badly broken that they are impossible to identify—all in a matrix of granular silicified limestone with abundant iron oxides and a well-crystallized calcite. Lacks fauna.
20. *Specimen T079, section no. 450*. By A. Sotomayor. *Field notes:* lava; barranca on the first stream beyond the Rio Zapotitlan (Chilac) on the road from Chilac to Atzingo. *Macroscopic description:* rose to reddish-coffee color. *Texture:* aphanitic. *Constituents:* labradorite, hematite, magnetite, pyroxenes. *Classification:* basalt.
21. *Specimen T076, section no. 448*. By A. Sotomayor. *Field notes:* reworked lava; barranca on first stream beyond the Rio Zapotitlan (Chilac) on the road from Chilac to Atzingo. *Macroscopic description:* massive porphyritic rock with light gray color. *Texture:* porphyritic with xenoliths. *Primary minerals:* andesine, magnetite, orthoclase. *Secondary minerals:* quartz, calcite, chlorite, oxides. *Comments:* the rock shows evidence of xenolithic granite and lavas. *Classification:* andesitic porphyry.
22. *Specimen T071, section no. 446*. By A. Sotomayor. *Field notes:* road in mountains about 3 km. east of Ajalpan. *Macroscopic description:* massive dark-gray and coffee-colored rock with quartz veins. *Texture:* cataclastic. *Constituents:* quartz, microcline, plagioclases, chlorite, sericite, limonite, secondary quartz. *Classification:* cataclasite.
23. *Specimen T072, section no. 447*. By A. Sotomayor. *Field notes:* volcanic tuff; road in mountains about 3 km. east of Ajalpan. *Macroscopic description:* fine-grained, green-colored rock. *Constituents:* fine-grained volcanic ash, plagioclases, oxides, calcite, chlorite; devitrification of original material. *Classification:* fine-grained volcanic tuff (ash-tuff).
24. *Specimen T044, section no. 444*. By A. Sotomayor. *Field notes:* dike some 200 m. before the Moctezuma bridge, Tehuacan-Huajuapan de Leon road (entering San Antonio Texcala). *Macroscopic description:* light-gray massive rock. *Texture:* aphanitic, aphyric. *Constituents:* labradorite, augite, magnetite, hematite, chlorite, limonite. *Classification:* augite basalt.
25. *Specimen T138, section no. 457*. By A. Sotomayor. *Field notes:* old *manantial;* slopes of Cerro Tepetroje southwest of Axusco. *Macroscopic description:* coffee-red breccia. *Texture:* clastic. *Detrital constituents:* limestone, sandstone, schist, quartz, feldspar, granite. *Cement:* calcite, hematite. *Classification:* calcareous breccia. *Origin:* hydroclastic sedimentary rock.
26. *Specimen T136, section no. 456*. By A. Sotomayor. *Field notes:* calcareous breccia; slopes of Cerro Tepetroje southwest of Axusco. *Macroscopic description:* coffee-red breccia. *Texture:* clastic. *Constituents:* limestone fragments, schist, altered rocks, quartz, feldspars, hematite, sandstone, chlorite. *Cement:* calcite, hematite. *Classification:* calcareous breccia. *Origin:* hydroclastic sedimentary rock.
27. *Specimen T157, section no. 459*. By A. Sotomayor. *Field notes:* calcareous breccia; between Cerro Pelon and Rio Salado, near Pueblo Nuevo, Puebla. *Macroscopic description:* white, cream, and coffee-colored breccia. *Texture:* clastic. *Detrital components:* limestone, silicified rocks, quartz, feldspars, chalcedony. *Classification:* calcareous breccia. *Origin:* hydroclastic sedimentary rock.
28. *Specimen T157b, section no. 64–2338*. By Dr. Federico Bonet and Enrique Riva Palacio. *Field notes:* calcareous breccia; between Cerro Pelon and Rio Salado near Pueblo Nuevo, Puebla. *Description:* greenish-gray, medium- or fine-grained, microcrystalline limestone, irregularly agrillaceous, with iron oxides and recrystallized veins. Lacks fauna.

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CHAPTER 6

The Human Skeletons

James E. Anderson

During the excavations in the Tehuacan Valley, human skeletal material representing, if only fragmentarily, more than seventy individuals was recovered from seven sites and from eight of the nine phases of the prehistoric cultural sequence. The importance of these bones lies in their antiquity (the six earliest burials being from the El Riego phase of about 6500–5000 B.C.) and in their scientific excavation in a cultural context with known dating. The bones are representative of a sequence spanning the transition from a nomadic food-gathering and hunting economy to that of full-time agriculturalists living in sizable communities.

This report grows out of the two intervals I spent in Tehuacan restoring and studying the skeletal material in January and July of 1964.* My emphasis in this report has been descriptive rather than metrical, with particular attention to morphological variations and pathology of bone and tooth. The objectives which guided the work included: the provision of basic population data for use in interpreting the archaeological record; the description of skeletal morphology for future comparisons as data become available from other sites; the search for temporal trends showing microevolution; the correlation of biological findings with culture change; and the study of the incidence of disease in early New World populations.

I measured crania and long bones according to the techniques described by Ashley Montagu (1960) and

Table 2. Burials from El Riego Cave West Niche (Tc 35w), by Phase and Level

	Lab or field no.	Age	Sex	Comments
Venta Salada				
Zone 1	A	adult	F	Infracranial fragments only
	B	adult	F	Fragments of skeleton
	C	adult	M	Almost complete except skull
	D	adult	F	Fragments of skeleton
	E	adult	M	Partial including mandible
	L1:1	under 6 mos.	?	Fragmentary
	L1:2	adult	F	Fragmentary, no skull
Zone 2	L2:1	adult	F	No skull, legs burned
	L2:2	newborn	?	Fragmentary
	L2:3	2–4 yrs.	?	Almost complete and intact
	L2:4	5 yrs.	?	Most of skeleton, part of skull
	L2:5	6 yrs.	?	Mandible and other fragments
Zone 3	L3:1	13 yrs.	?	Fragmentary skull and teeth
	L3:2	adult	F	Fragmentary skull and teeth
Palo Blanco				
Zone 4	L4:1	adult	M	Fragmentary, partly burned
	L4:2	11 yrs.	?	Fragmentary, partly burned
El Riego				
Zone 5	L5:1	adult	F	Cremated fragments
Ajuereado				
Zone 6	L6:1	adult	?	Fragment of mandible
Unclassified		adult	F	Almost complete; looted grave

* I am pleased to record my gratitude to the R. S. Peabody Foundation for Archaeology and to Dr. Richard S. MacNeish for making it possible for me to study this important collection. I owe a great debt to Dr. MacNeish for his stimulating guidance in the interpretation of the material and to Mrs. MacNeish for her kindnesses while I was at Tehuacan.

During his visit to the site, Dr. Santiago Genoves was most helpful in discussing criteria for determining age and sex and in providing literature on Mexican osteology. Through the kindness of Dr. Arturo Romano I was able to examine skeletal material in the National Museum of Mexico, where Señorita Teresa Jaen was most helpful. I am particularly indebted to Dr. Charles Goff for his guidance in interpreting some of the pathological specimens.

Table 3. Burials from El Riego Cave East Niche (Tc 35e), by Phase and Level

	Lab or field no.	Age	Sex	Comments
Venta Salada				
Zone B	B:I	adult	F	Fragmentary
	B:II	adult	M	Fragmentary
	B:III	15 mos.	?	Fragmentary skull and teeth burned black
Zone C	C:I	adult	F	Partial, some bones burned black
	C:II	under 2 yrs.	?	Fragmentary
Palo Blanco				
Zone D	D:I	adult	M	Fragmentary
	D:II	adult	F	Fragmentary
	D:III	newborn	?	Fragmentary
Zone E	E:I	adult	?	Fragmentary, burned

Table 4. Burials from Coxcatlan Cave (Tc 50), by Phase and Level

	Lab or field no.	Age	Sex	Comments
Venta Salada	7	adult	F	Jaws, teeth, other fragments
Palo Blanco	1	15 mos.	?	Complete, desiccated tissue
El Riego				
Zone XIV	2	5 yrs.	?	Almost complete, broken skull
	3	under 6 mos.	?	Almost complete
	4	adult	M	Burned black, almost complete
	5	adult	F	Almost complete
	6	under 6 mos.	?	Almost complete, broken skull

estimated stature on the basis of the length of limb bones, using the formulae of Trotter and Gleser (1958). The age of immature individuals was determined by the stage of dental eruption and the progress of epiphyseal fusion. Since the symphysis pubis was rarely available for study in the adult skeletons, only the relative age could be judged on the basis of degenerative changes in the bones, the degree of wear on the teeth as related to the cultural level, and the state of suture closure. Examination of the pelvis, the skull, and the articular areas of the appendicular skeleton helped to determine the sex of the skeletons. When other areas were equivocal, pelvic criteria as described by Genoves (1962) were given priority. Also the size of joint surfaces, particularly the diameter of the femoral head, was used in determining sex, rather than the length and robustness of the long bones (Anderson 1963).

Tables 2–8 summarize the burial data for each of the sites which yielded human skeletal remains. Some of the skeletons were given burial numbers in the field, other fragmentary remains were given numbers in the laboratory, and a few remains are identified by the level of excavation in which the burials were found.

In the following descriptions of the burials, the order follows the chronological sequence established for the Tehuacan Valley, beginning with the most ancient material and proceeding toward the present. The material is grouped according to cultural phase.

Ajuereado Phase

This, the earliest phase, ended before 6500 B.C. The population consisted of nomadic microbands whose subsistence depended on the collection of wild plants and the hunting and trapping of game.

The only human skeletal material recovered from this phase, a fragment of the left side of an adult mandible, was found in the West Niche of El Riego

Table 5. Burials from Ajalpan Site (Ts 204), by Level (all Ajalpan Phase)

	Lab or field no.	Age	Sex	Comments
"Burial 1"	1	adult	M	Long bones and mandible
Zone F	2	adult	M	Fragments
	3	adult	F?	Fragments
Zone G	4	subadult	M	Fragments
Zone G'	5	adult	M	Fragments
	6	adult	F	Fragments
Zone H	7	adult	?	Fragments

Table 6. Burials from Quachilco (Tr 218), by Phase

	Lab or field no.	Age	Sex	Comments
Palo Blanco	1	adult	M	No skull or teeth
Santa Maria	2	adult	M	Almost complete
	3	8 yrs.	?	Almost complete
	4	adult	M	Almost complete
	5	6 yrs.	?	Teeth, skull and other fragments
	6	adult	F	Teeth, fragmentary skeleton
	7	adult	M	Teeth, part of skull, other bones
	8	adult	M?	No skull or teeth
	9	adult	M	Fragmentary

Note: Fragments found in Zone A are probably parts of Burial 1. Fragments recovered from Zones B, B', C, and C' are probably parts from Burials 2–9, particularly Burial 5.

Table 7. Burials from Purron Cave (Tc 272), by Phase and Level

	Lab or field no.	Age	Sex	Comments
Palo Blanco				
Zones C-E	1	adult	F	Fragmentary
Abejas				
Zone M	–	adult	?	Tibial fragment
	–	adult	?	Pelvic fragments
Zones N-O	3	adult	M	Fragmentary; parts added from Zone N^1.
Zones O-P	–	adult	?	Pelvic fragments and R. calcaneus
Coxcatlan				
Zones P-Q	–	adult	?	Cuboid, calcaneus, fibula
Zone Q^1	–	adult	?	Rib fragments, lumbar vertebra
Zones Q^1-R	2	adult	M	Partial skeleton
El Riego				
Zone R	4	adult	F	Partial skeleton

Table 8. Burials from Coatepec (Ts 368e), by Phase and Level

	Lab or field no.	Age	Sex	Comments
Venta Salada				
Zone A	–	young	?	Fragments
	–	subadult	?	Fragments
Palo Blanco				
	1	17 years	?	Fragments
Santa Maria				
	3	2 years	?	Fragmentary
Zone C	–	adult	?	Femur fragments
Zone C^1	–	adult	?	Vault fragments, teeth
Zone D	–	adult	?	Two small frontal fragments
Ajalpan				
Zone K	–	adult	?	Burned mandible, vault, talus
	–	subadult	?	Mandibular fragment
Zone K^1	–	adult	?	Burned left talus
Zone K^2	2	adult	M	Infracranial fragments
Zone K^3	–	adult	?	R. frontal, L. maxilla, teeth

Cave. The chin is square or bilateral in form with prominent mental eminences. The mental foramen is double. Only two teeth are in place. The first premolar is worn down almost to the neck, exposing its pulp chamber and resulting in an apical abscess. The third molar is tilted mesially toward the space formerly occupied by the long-lost first two molars, whose alveoli have been resorbed.

El Riego Phase

This period spans the years 6500 to about 5000 B.C. The people subsisted on a low-level hunting economy in the dry season and exploited the lush vegetation of the wet season.

Human material comes from three sites: Burial 4 at Purron Cave, Burials 2–6 from Coxcatlan Cave, and a fragmentary burial from Zone 5 of the West Niche of El Riego Cave.

Tc 272, Burial 4. This fragmentary skeleton from Purron Cave is dated about 6000 B.C. The bone is soft and friable and deeply stained by red ochre. The skull vault is badly warped and the frontal region is crushed. The temporal bones are complete, but the facial skeleton is represented by only the left zygoma. There are two mandibular fragments and nine loose teeth. The limb bones are all represented, but are badly damaged, particularly at their joint surfaces. All segments of the vertebral column are present, but most are badly preserved.

The skeleton is probably that of a female, judging from the delicacy of its supraorbital ridges and mastoid processes, marked parietal bossing, indistinct muscular markings in the nuchal region, feminine conformation of the right ischial notch, and a femoral head

Fig. 52. The skull of Tc 50, Burial 4; El Riego phase; adult male; reconstructed from 58 pieces of burned bone. Note continuous supraorbital ridge, large infraorbital foramina, and zygomatic region which appears vertical in side view and flat when seen from below.

Fig. 53. The skull of Tc 50, Burial 5; El Riego phase; adult female. Note short, broad mandibular ramus; gonial eversion, vertical malar region; prominent zygomaxillary tuberosity; and narrow space for the nasal bones.

diameter of only 40 mm. Although the vault sutures of this adult remain distinct, there are signs of the aging process in the osteophytosis of the vertebral body margins. The stature was estimated from the length of the ulna as 167.8 $\pm$ 4.66 cm., or approximately 5 feet, 6 inches. This estimate may be distorted since it falls outside the range of the other estimated statures for females given in Table 12 below.

The neurocranium appears short, with its greatest height above the marked parietal bosses. The cranial index is estimated at 78.3, which is in the mesocranial range. The only Wormian bones are tiny inclusions in the lambdoid suture and there is no sagittal crest or metopic suture. On both sides there are supraorbital notches, but the vessels and nerves leave no grooves on the frontal bone. The supraorbital ridges are continuous across the midline. The occipital region consists of a low mound and a ridge. Both tympanic plates are slightly thickened but have no dehiscences.

A fragment of right mandible shows complete resorption of its alveolar bone, following the loss of all posterior teeth. The anterior teeth are severely worn in an asymmetrical fashion, with oblique slopes on one or more surfaces exposing the dentin of the crown and leaving short crescents of enamel projecting on the occlusal surface. One premolar has a carious lesion in the cervical region of its distal surface which has opened into the pulp chamber.

There is flattening of the femur, but not of the tibia: the platymeric index is 71.9; and the platycnemic index is 74.2. There is no vastus notch or third trochanter, but a large septal aperture is present on the left humerus. Anterior and middle facets on the calcaneum are discrete. The articular surfaces of both patellae have central pitted areas diagnostic of early osteoarthritis. Vertebral body fragments show moderate peripheral osteophytosis. There is a healed fracture of the distal end of the left radius with the characteristic "dinner fork" deformity, but no signs of fracture on the ulna.

Tc 50, Burial 2. This burial from Coxcatlan Cave is the almost complete skeleton of a five-year-old child, found in the same grave with the skeleton of a still younger child (Burial 3). The heads of both children had been removed from their bodies and were exchanged in burial. Although all parts of the skull properly belonging to Burial 2 were present, the skull could not be reconstructed. The occipital region may have been broken in before burial, and there was some evidence of charring.

The age of the child was estimated as five years on the basis of the following evidence: All parts of the temporal bone have fused and lateral growth of the tympanic plate is almost complete. Its lateral edge is lacelike, and dehiscences are present bilaterally. The mastoid process is well developed for the age of the skull. The fusion of the condylar to the squamous part of the occipital bone is incomplete. All the deciduous teeth have erupted, and the crowns of the first permanent molars are just at the alveolar margin. The limb epiphyses have not yet fused. The atlas vertebra consists of the unfused right and left neural arches and a separate anterior arch segment. Its foramen transversarium has not quite formed. The axis vertebra is complete except for the fusion of the os apicis and the closure of the foramen transversarium. The other cervical vertebrae have fused neural arches, but two arches have not fused to the centrum. The upper eight thoracic vertebrae have arches completely united to their centra, but the lower four show recent fusion. In the lumbar region arch and centrum are well fused, except for L4 and L5, which show spina bifida (see Fig. 65 *b*). The neural arch of the sacral elements has fused to the ala, but the latter has not fused with the body. The sacral canal is widely open posteriorly for its whole length. There is a pseudo-epiphysis on the first metatarsal.

On each side of the skull there is a large Wormian bone in a deep parietal notch. Supraorbital notches are bilateral, but no grooves may be seen. There is a prominent tuberosity mainly on the zygomatic process of the maxilla. The only wear shown by the teeth is a flattening on the cusps of the deciduous molars. The upper left central incisor had been lost, and its socket is the site of an alveolar abscess.

Tc 50, Burial 3. The skeleton is of an infant less than six months of age. The skull had been exchanged in burial with the skull of Burial 2. Unfused are: the symphysis menti, the parts of the occipital bone, the metopic suture, and the limb epiphyses. The squamous and petrous parts of the temporal bone have fused, but the tympanic ring shows no signs of lateral growth. The crowns of the deciduous teeth are forming and their alveoli are open. In the vertebral column fusion of the two halves of the neural arch has not begun.

Tc 50, Burial 4. This is the skeleton of an elderly male, most of whose bones are burned black. The skeleton was found in a grave with Burials 5 and 6. The sex was determined from the heavy brow ridges and nuchal markings, male sacral proportions and ischial notch, and the robustness of the limb bones. Cranial sutures are obliterated, and there is advanced degenerative disease of the joints.

The skull was reconstructed from fifty-eight pieces. Its vault is mesocranial in proportions. The supraorbital ridges are continuous. The facial region is flat with large zygomaxillary and malar tuberosities. The occipital region is mound shaped. The chin form is mediobilateral, and there is slight gonial eversion and a mylohyoid arch on both sides.

The jaws are toothless with resorbed alveoli, except for three short tooth roots. Advanced attrition had exposed the pulp chambers of these and resulted in apical abscesses.

Stature estimated from the length of the tibia is 165.1 $\pm$ 3.27 cm., or 5 feet, 5 inches.

Most of the available joint surfaces, especially the apophyseal joints of the cervical vertebrae, show signs of osteoarthritis. Osteophytosis of the vertebral bodies is most marked in the lumbar region. A compression fracture of the third thoracic vertebra has caused its body to become wedge-shaped and to fuse to the vertebral body above by a large osteophyte on the left side. The fifth lumbar vertebra exhibits spondylolisthesis, the anterior slipping of its body being shown by lipping on the periphery of the first sacral body.

There is an old healed fracture of the right fifth metatarsal. Fractures are present at the midshaft of the left radius and ulna, where healing has occurred with considerable angulation. Two rib fragments also show signs of healed fracture.

Fig. 54. *a*, Child of 2–4 years, Tc 35w; Venta Salada phase; with typical large tuberosity. *b*, Tc 35w, Burial C; adult male; Venta Salada phase. *c*, Tc 35w; looted burial; adult female. *d*, Tr 218, Burial 2; adult male; Santa Maria phase; treponemal infection has destroyed most of the vault.

Tc 50, Burial 5. The skeleton of an adult female was found with Burials 4 and 6. The sex was determined on the basis of pelvic and cranial criteria, as well as by the femoral head diameter of only 39 mm. Although vault sutures are still distinct, degenerative changes throughout the skeleton suggest at least middle age.

The skull was completely reconstructed. Wormian bones occur as inclusions in the lambdoid suture as well as bilateral parietal notch bones. The facial region is flat, with small malar tuberosity and marginal tubercle, but with a huge zygomaxillary tuberosity formed jointly by the two bones. An occipital mound extends from the lambda to the inion. The chin is median in shape. Gonial eversion is evident, and there are bilateral mylohyoid arches. Apparent maxillary alveolar prognathism has resulted from the loss of many teeth. The foramen spinosum is open medially on both sides.

Fig. 55. The skull of Tr 218, Burial 7; adult male; Santa Maria phase; cranial index, 82.2. Note frontal slope, flat vertical occiput, "rocker"-shaped lower border of mandible.

Early temporomandibular joint arthritis is shown by eroded areas on both articular eminences.

Half of the teeth had been lost and the alveoli resorbed. Advanced wear on the remaining teeth left oblique surfaces, exposing secondary dentin and sometimes the pulp chamber. Sharp crescents of enamel remain on the occlusal surfaces. The palate is eroded by extensions from alveolar abscesses.

Stature calculated from fibular length is 159 ± 3.24 cm., or 5 feet, 3 inches.

Perhaps even more than her colleague, Burial 4, this skeleton is riddled with degenerative and traumatic changes. Osteoarthritis is present in both hips, both first metatarsophalangeal joints, the acromioclavicular joints, the left ankle joint, and at the vertebral apophyseal joints. There is advanced osteophytosis in all regions of the spine.

Compression fractures occur throughout the vertebral column: C4, C5, T4, and T7 have been crushed to approximately half their normal thickness, and the bodies of T8 and T12 have become wedge shaped.

The left scapula exhibits signs of an old fracture of the body which healed with infection. From a large central defect, three fracture lines radiate to the periphery of the bone. The fragments have slightly overlapped each other, giving the region of healing a pleated appearance. Along the fracture line are round regular holes representing abscesses which failed to be contained by the thinness of the blade of the scapula. Three left ribs underlying the scapula also show signs of healed fractures.

Both humeri have septal apertures, but there is no vastus notch or third trochanter.

Tc 50, Burial 6. The third component of the multiple burial is the skeleton of an infant less than six months of age. The skull is badly fragmented. Immaturity is shown by the lack of fusion of the symphysis menti, the parts of the occipital bone, the vertebral neural arches, and the limb epiphyses. The four parts of the temporal bone have fused, but there has been no lateral growth of the tympanic ring.

Tc 35w, Zone 5. This level of El Riego Cave contained a cremation consisting of small fragments of limb, vertebrae, and skull. The delicacy of the bones suggests that they are those of an adult female. A burned canine tooth shows evidence of cervical caries.

Summary. Seven individuals of the El Riego phase are represented from three sites: at Purron Cave the single extended burial of an adult male; at Coxcatlan Cave two multiple burials, one consisting of two children whose heads had been removed and exchanged, the other consisting of three individuals, a burned elderly male, a somewhat younger female, and an infant; at El Riego Cave a cremated adult female.

The skulls are uniformly mesocranic, with a low occipital mound and the highest part of the vault occurring above the parietal bosses. The faces are flat with a prominent zygomaxillary tuberosity present even in children.

The unusual pattern and advanced state of the wear on the teeth is probably the result of fibrous and gritty vegetable material being pulled through the teeth during mastication. The teeth are worn down obliquely, leaving a crescent of enamel on the crown and often exposing the pulp chambers. Loss of teeth under these conditions was extreme. Caries is not common, and when present, results from the impaction of food between teeth.

The very high incidence of healed fractures exhibited by two skeletons from the same grave is noteworthy.

Coxcatlan Phase

This period, dated roughly from about 5000 B.C. to 3500 B.C., is one of incipient agriculture, but there is still a great reliance on wild foods. Skeletal material from this phase comprises only Burials 2 and 3 from Purron Cave, dated about 4300 B.C., and some fragments found at related layers of the same site.

Tc 272, Burial 2. This damaged skeleton of an adult male is rather curiously incomplete, lacking the left forearm and lower limb.

The skull vault differs considerably from any others from the Tehuacan sites. It is relatively long and low, with some heightening behind the marked parietal bosses. The estimated cranial index is 68.3. There is a prominent mound-shaped occiput. The supraorbital ridges are heavy, continuous, almost straight, extend the full width of the orbit, and blend with the supraorbital margin. Behind them, the postorbital region appears constricted, although the minimum frontal diameter of 88 is not extremely small. The mastoids are big and bulky with a huge suprameatal "torus" and a deep triangular suprameatal pit. The mandible has very strong mental eminences which result in a subsymphyseal concavity. There is gonial eversion.

The dental picture resembles that seen in the El Riego phase, with marked oblique attrition producing enamel crescents on the occlusal surfaces of the teeth. There is evidence of three abscesses, and periodontal disease shows in the marked recession of the alveolar margin and exposure of the roots.

The limb bones appear long, straight, and very robust. The linea aspera is spectacular. Stature calculated from the length of the femur is 168.8 ± 3.8 cm. (5 feet, 6 inches).

Osteoarthritis appears only in the cervical apophyseal joints. This and the peripheral lipping of the bodies encroaches on the foramina transversaria. Two ribs show signs of healed fractures.

Tc 272, Burial 3. This burial consists of a mandible, five loose upper teeth, and the fragmentary infracranial skeleton of an adult, probably a male. The crowns of most teeth have been worn almost flat, exposing the dentin. Enamel forms a ring on the occlusal surface, surrounding a depressed zone of dentin. The lower left third molar is unworn (it evidently was unopposed) and so has a carious lesion in a deep distolingual pit on its crown. The mandible is robust and has a medio-bilateral form of chin. The only pathology noted on the infracranial fragments is advanced lipping of one lumbar vertebral body.

Tc 272, Fragments. Fragments of adult cuboid, calcaneum, fibula, rib, and vertebra were found in Zones Q^1, Q, and P of Purron Cave.

Abejas Phase

During this period, extending from about 3500 to 2300 B.C., the population of the valley alternated between hunting camps during the dry season and pit houses on river terraces during the wet season. An increasing amount of food was being grown under cultivation. Unfortunately, we have only one burial from this phase and a few pieces of lower limb bone from Zone M of Purron Cave.

Fig. 56. The skull of Tr 218, Burial 4; adult male; Santa Maria phase. Note prominent, straight, continuous supraorbital ridge; blurred subnasal margin; alveolar prognathism; strong suprameatal crest. Mandible shows the typical ridged and everted gonial angle.

Purron Phase

This phase, which lasted from about 2300 to 1500 B.C., is the least understood segment of the sequence. Pottery was first produced during this period. No human skeletal material has been recovered from the two excavated floors.

Ajalpan Phase

This phase lasted from 1500 B.C. to about 900 B.C. The population consisted of full-time agriculturalists occupying small villages. The skeletal material, representing probably twelve individuals, comes from two sites: Coatepec (Ts 368e) and Ajalpan (Ts 204 and Ts 204c).

Ts 368e, Burial 2. These remains from Coatepec consist of a few fragments of an adult skeleton, mainly pelvis and scapula, with evidences of burning. The ischial notch is that of a male.

Ts 368e, Zone K. This level contained what are probably parts of two individuals: (*a*) A burned fragment of adult mandible with teeth charred and their crowns broken. There is evidence of loss of teeth, both before and after death. There are also rib fragments, parts of the skull vault in which the bone is very thick, and a left talus. (*b*) A fragment of the left side of a subadult mandible with three molar teeth. The first molar has

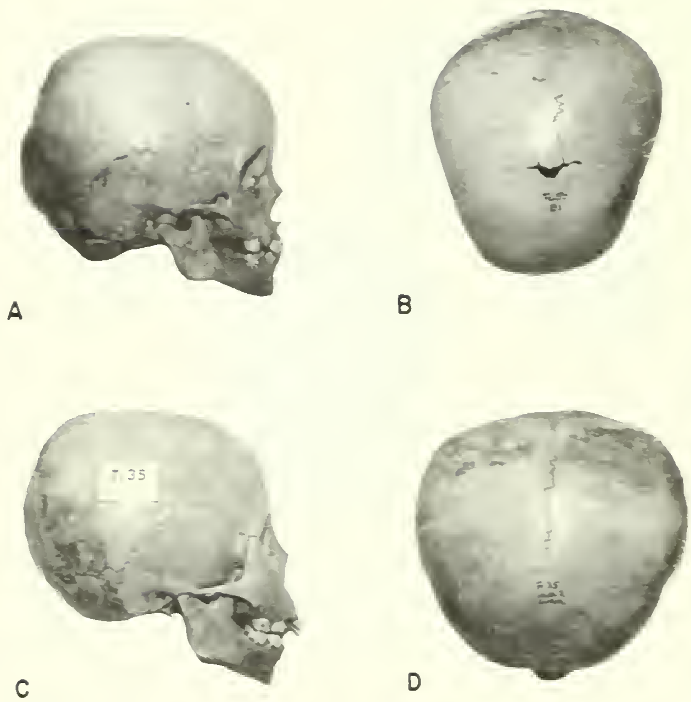

Fig. 57. Two immature skulls showing different vault forms. *Above:* Tc 50, Burial 1, Palo Blanco phase. *Below:* Tc 35w, Zone 2, 2–4 years old, Venta Salada phase. Measurements are given in Table 10.

blunted cusps, the second was lost after death, and the crown of the unerupted third lies in its alveolus.

Ts 368e, Zone K^1, contained a burned left talus.

Ts 368e, Zone K^3, yielded a fragment of a right frontal bone and part of a left maxilla bearing three teeth. Attrition has exposed dentin on the lateral incisor, but has only blunted the cusps of the canine and first premolar.

Ts 204, Burial 1. This burial from the Ajalpan site consists of many split fragments of long bones and a partially restored mandible of an adult whose robustness suggests that he is male. The chin is of medio-bilateral form. Many teeth have been lost with subsequent resorption of the alveolar process. Cusps are worn flat, exposing the dentin in their cores. Two premolars share approximal caries resulting from food wedged between them, and a canine has a small cervical carious lesion.

Ts 204, Zone F, contained bone fragments probably representing two individuals: (*a*) Fragments of ribs, the shaft of a humerus, a right patella, and a piece of right mandible with empty alveoli owing to postmortem tooth loss. The chin form is medio-bilateral, and there is no gonial eversion. General skeletal robustness suggests that this individual was probably a male. (*b*) Fragments of ribs, a left adult radius, and a mandible with chin of median form. Loss of teeth was followed by alveolar bone resorption.

Ts 204, Zone G, yielded a frontal and a left parietal fragment, the shaft of a left humerus, femoral condyle fragments, and the left mandibular ramus of a subadult male. The supraorbital ridges are continuous and extend for half of the width of the orbit. Minimum frontal diameter is 95. The root of the nasal bones is broad. The third molar has not yet erupted. There is slight gonial inversion and no mylohyoid arch. The breadth of the ramus is 34 mm. and the height is 57 mm.

Ts 204, Zone G^1, contained parts of two individuals: (*a*) a frontal bone fragment with sharp supraorbital margins, probably that of an adult female; (*b*) a humeral head with a diameter of 0.41 mm., a femoral condyle fragment, and a left adult male patella with a few bony spurs extending into the quadriceps attachment.

Ts 204, Zone H, contained fragments of an adult skeleton of indeterminate sex: proximal end of right ulna, ribs, left mandible, and loose premolars. The mandibular fragment shows premortem tooth loss. The premolar crowns are worn flat and one exhibits large mesial cervical caries.

Summary. If we maintain the distinctness of the bones at each level, the fragments from components of the Ajalpan phase represent five individuals from Coatepec and seven from Ajalpan. One skeleton from each site is a subadult. The absence of child skeletons may be noteworthy. Evidence of burning is found in only one skeleton. The pattern of dental attrition has changed with the switch to an agricultural economy: the wear is not as severe and is no longer oblique. Loss of teeth continues to be serious, but is now caused by caries.

Santa Maria Phase

During this phase, dating from before 900 B.C. to about 200 B.C., a population of full-time farmers using irrigation lived in villages oriented around a larger community with ceremonial structures. The skeletal material comes from eight burials at Quachilco and from certain zones at Coatepec.

Tr 218, Burial 2. This almost complete adult male skeleton from Quachilco is one of the most interesting specimens among the human materials. Much of the vault of the skull is missing. Examination of the remaining areas supplies the explanation for its fragility. A widespread osteitis of the neurocranium, sparing only the squamous temporal, has eroded the external surface in an irregular manner and in some areas has

completely penetrated the skull. Surrounding these diffuse lesions are unevenly deposited plaques of new bone. The irregular "worm-eaten" appearance is typical of a treponemal infection, probably syphilis.

The chin is bilateral in form, and shows some gonial eversion. There is a well-marked ossification of the apical ligament's attachment to the anterior margin of the foramen magnum.

Attrition has exposed the dentin on the incisors and canine teeth, but has only blunted the cusps on the posterior teeth. Six teeth are carious, and five have been lost and the alveoli resorbed. Crowding has resulted in slight mesial rotation of the upper left central incisor and the lingual eruption of the lower left lateral incisor.

Stature determined from the length of the fibula is 157.3 ± 3.24 cm. (5 feet, 2 inches). Very little osteophytosis is found in the vertebral column except on C3 and C4, which are markedly lipped and fused with each other at body and apophyses, but not at the laminae.

Tr 218, Burial 3. This is the almost complete skeleton of an eight-year-old child. The first permanent molar is at the occlusal plane, as are the upper four incisors. The posterior deciduous teeth were sufficiently worn to expose the dentin. Crowding is shown in the mesial rotation of both upper central permanent incisors.

Supraorbital notches are bilateral. The typical zygomaxillary tuberosity is huge, and the chin is medio-bilateral in form.

All vertebrae show union of the halves of their neural arches, which in the cervical and upper thoracic region have also fused to their centra. The anterior arch segment of the atlas and the os apicis of the axis have not fused. The foramen transversarium is absent on the left side of C6 and C7.

Tr 218, Burial 4. The almost complete skeleton is that of an adult male. The mesocranic skull has multiple tiny Wormian bones in the right coronal suture. On each side is a supraorbital foramen, but there are no grooves on the frontal bone. The supraorbital ridge is a continuous long low bar which blends with the superior orbital margin. The chin is bilateral in form, and there is gonial eversion. On the left side, an anteromedial spur projects into the foramen ovale.

Attrition has exposed the dentin on the anterior teeth, and has blunted the cusps on posterior teeth. There are many pits on the enamel of molars; two are carious. Crowding has resulted in the mesial rotation and labial eruption of the upper central incisors, and in the lingual displacement of the lower left central incisor.

There is acromioclavicular joint arthritis and slight

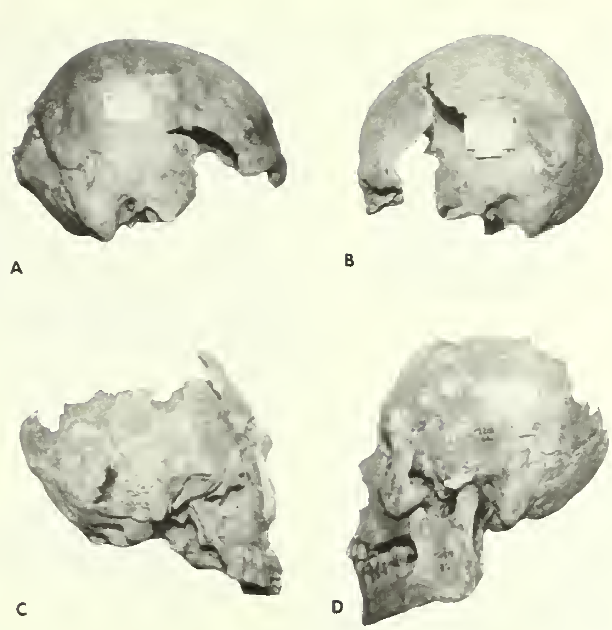

Fig. 58. *a*, Right side of the vault, Tc 272, Burial 2; adult male; Coxcatlan phase. *b*, Left side of the vault, Tc 272, Burial 4; adult female; El Riego phase. *c*, *d*, Right and left sides of the skull, Tr 218, Burial 2, showing the treponemal destruction of the vault.

vertebral osteophytosis. The sacrum consists of only four elements and has accessory articulations with L5.

Tr 218, Burial 5. This burial consists of the fragmentary remains of a six-year-old child. The first permanent molar has erupted. Dentin is exposed on the incisors, and there are cusp facets on the posterior deciduous teeth. The chin is medio-bilateral, and gonial eversion is prominent. There is no mylohyoid arch, but there are accessory mandibular foramina on each side.

Tr 218, Burial 6. This burial consists of teeth and bone fragments of an adult female. The chin is bilateral, and there is gonial eversion. The anterior teeth have exposed dentin; the posterior teeth have cusp facets. There has been labial eruption and rotation of the lower right canine. The lower central incisors are worn down severely by a groove on their labial surfaces that runs downward and to the right. The enamel of all teeth appears mottled.

There is an anomalous foramen in the right upper part of the anterior surface of the manubrium.

Tr 218, Burial 7. This specimen consists of the skull, teeth, and fragmentary infracranial skeleton of an adult male. The vault is high, short, and round, and the estimated cranial index is 82.2. The supraorbital ridges are continuous. The occiput is mound shaped. The chin is medio-bilateral in form, and there is gonial eversion.

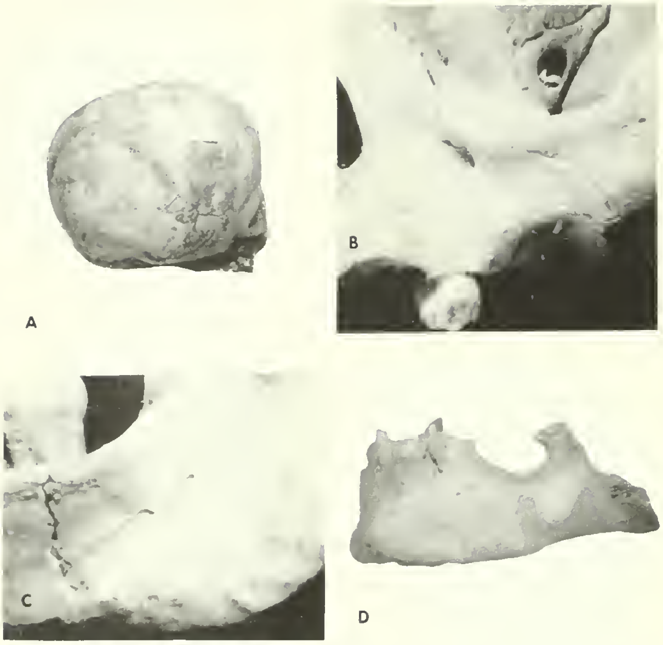

Fig. 59. *a*, Posterior of the skull of child 2–4 years old, Tc 35w, showing ten wormian bones in the right lambdoid suture. *b*, Detail of left face, Tc 50, Burial 1, a child, Palo Blanco phase; an infraorbital suture is still distinct and bounds an accessory infraorbital foramen. *c*, Internal surface of the mandibular ramus, Tc 50, Burial 7, Venta Salada phase, showing a mylohyoid arch over a groove which forms at some distance from the mandibular foramen. *d*, A mandibular fragment from Tc 35w, Ajuereado phase, with a double left mental foramen.

Only three teeth are present, most having been lost before death and the alveolar bone resorbed. One of the teeth is carious.

There are accessory facets between L5 and S1. The sacrum is damaged at the level of its fourth body so that it is impossible to tell the number of sacral segments. There is slight osteophytosis of the lower lumbar region.

Tr 218, Burial 8. The fragmentary infracranial skeleton is that of an adult, probably a male. No lower limb bones are represented.

Tr 218, Burial 9. This burial consists of fragments of cranium, mandible, and infracranial parts of an adult male. Anterior teeth have exposed dentin. The enamel of the molars is characterized by pits and fissures, six of which have become sites of carious lesions.

Ts 368, Burial 3. This fragmentary burial from Coatepec represents a two-year-old child.

Ts 368, Zones C, C[1], and D. Scattered human material from these levels consists of fragments of an adult femur and cranial vault and a lower premolar with blunted cusps.

Summary. The human material from the Santa Maria phase consists of six adults and two children from Quachilco, and a child and at least one further adult from Coatepec. Certain general observations may be made: (*a*) There are no evidences of burned bone. (*b*) Cranial vaults are shorter, higher, and rounder. (*c*) Teeth are less worn, but enamel pits and fissures have become the site of caries. (*d*) The crowding of incisors and the labial grooves on the lower incisors of one individual may correlate with the finding of lip plugs in this complex. (*e*) Two individuals have accessory lumbo-sacral articulations.

Palo Blanco Phase

The population from 200 B.C. to A.D. 700 had developed a more sophisticated agricultural economy and lived in villages oriented to large hilltop sacred cities.

The skeletons from this complex consist of individual burials from Coxcatlan and Purron caves, from Quachilco and Coatepec, as well as scattered bones from the two niches of El Riego Cave.

Tc 50, Burial 1. The skeleton of a fifteen-month-old child from Coxcatlan Cave is complete. Some soft tissue has been desiccated and preserved.

The cranial vault is short and wide with prominent bossing. The posterior pole appears asymmetrical because of a more prominent left occiput, and there is a wide supralambdoid sulcus. The zygomaxillary tuberosities are very large. The chin region is median in form, and there is gonial inversion. The deciduous dentition is complete except for unerupted second molars and canines that are half way to the occlusal plane.

The atlas vertebra is in three segments and its foramen transversarium is incomplete. Neither the dens segment nor the os apicis has fused to the axis, although the neural arch is united to the centrum. The spurs surrounding the foramen transversarium almost meet. The halves of the neural arch of the other cervical vertebrae have united, but the centrum remains discrete in each. The foramen transversarium is almost closed. The fifth cervical vertebra has a separate lateral element on each side which forms the external border of the foramen transversarium. This foramen is double on the right side of C7. In other regions the neural arches have not fused to the centra.

Tr 218, Burial 1. The fragmentary skeleton from Quachilco of an adult male possessed no skull or teeth. There are slight arthritic changes in the limb joints.

Tc 272, Burial 1. This fragmentary skeleton from

Purron Cave represents an adult female. The three loose teeth do not show much wear, but one shows caries. There is early osteophytosis in the lower lumbar and the sacral region.

Ts 368, Burial 1. This burial from Coatepec is the partial infracranial skeleton of a youth about seventeen years old. Elbow epiphyses have fused, but those at the shoulder and wrist have not. Union of the head to the shaft of the femur has begun. The symphysis pubis is transversely ridged, and the vertebrae are complete except for their secondary centers. There is a large septal aperture on the only humerus available, the left.

Tc 35w, Zone 2. The West Niche of El Riego Cave contained a skeleton consisting of many small damaged fragments of partially burned friable bone with black crystalline accretions on the surface.

The age represented by the skeleton is estimated as eleven years. There are wear facets on the cusps of the first permanent molars and the second molars are just beginning to erupt. The long-bone epiphyses have not united. In the vertebral column the neural arches and centra have united. The axis shows recent fusion of the os apicis, but the dens segment has been united to the body for a long time.

Tc 35w, Zone 4. This level contained the fragmentary burial of an adult male. The bones show varying degrees of burning.

Tc 35e, Zones D and E. Fragments probably representing four individuals were found in two levels of the East Niche of El Riego Cave: (*a*) an adult male with occlusal caries on a premolar, (*b*) an adult female with only slight dental attrition, (*c*) a newborn child, and (*d*) the burned remains of an adult of indeterminate sex.

Summary. Material representing the Palo Blanco phase was collected from six sites and consists of ten individuals, mainly fragmentary, of whom three are immature and three show signs of burning. The teeth show less wear than in earlier periods and an increase in the incidence of caries.

Venta Salada Phase

The most recent material comes from the Venta Salada phase of about A.D. 700 to 1540. There were five burials and many partial remains from the West Niche of El Riego Cave and fragmentary remains from the cave's East Niche, Burial 7 from Coxcatlan Cave, and fragments representing two individuals from Coatepec.

Tc 35w, Burial A. From the West Niche of El Riego Cave came a badly weathered fragmentary infracranial skeleton of an adult female.

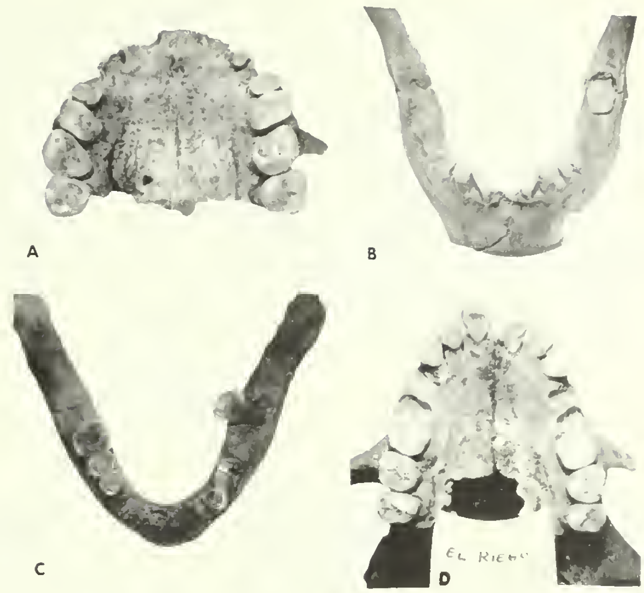

Fig. 60. *a*, *b*, *c*, Advanced, oblique wear is characteristic of teeth of the earliest skeletons; *c* shows exposed dentin and remaining crescents of enamel. *d*, Teeth from a later phase show little wear; numerous enamel pits on the molar crowns are not carious because in life they were effectively plugged by calculus.

Tc 35w, Burial B. This is the partial skeleton of a young adult female. The teeth show very little attrition. The enamel of the molars is riddled with pits and fissures, most of which were plugged with a calculus deposit, and only one of which is a site for caries. The buccal surfaces of the lower right canine and first premolar are involved with a deep carious lesion which seems to have been preceded by a traumatic groove. There is an area of minimal periostitis on the midshaft of the right tibia.

Tc 35w, Burial C. The almost complete skeleton and partial skull represents an adult male. The anterior surface of the zygoma is oblique rather than vertical, as was typical of earlier skeletons. The facial skeleton is rugged with large malar tuberosity, marginal tubercle, and zygomaxillary tuberosity.

The dentition is complete and shows slight attrition. Deep enamel pits on the molar crowns have been plugged with calculus and are not carious.

Stature estimated from the length of the femur and fibula is 163.8 ± 3.18 cm. (5 feet, 5 inches).

Tc 35w, Burial D. The partial infracranial skeleton and a segment of the right mandible represent an adult female. One of three available teeth is partially destroyed by caries. The acetabulum is shallow, elon-

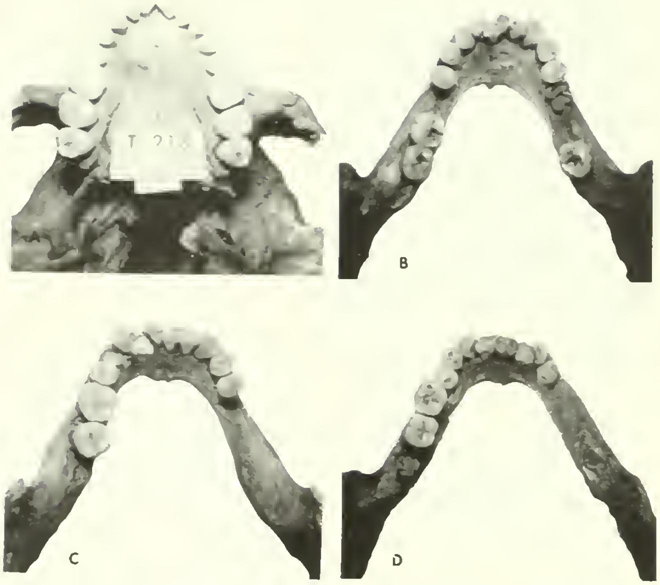

Fig. 61. Evidence of crowded teeth in jaws from Tr 218, Santa Maria phase. *a*, Central incisors erupted labially and are mesially rotated. *b*, The left central incisor is lingually displaced and the left lateral incisor is distally rotated. *c*, Left lateral incisor is tilted lingually. *d*, The right canine erupted labially.

gated to a long oval shape, and has a poorly defined anterior border.

Tc 35w, Burial E. The skull fragments of this partial skeleton of an adult male are burned black. There are widespread evidences of osteoarthritis and an old healed fracture of the shaft of the left fibula.

Tc 35w, Zone 1. This level contained fragmentary remains of two individuals: (*a*) an infant less than six months of age and (*b*) an adult female.

Tc 35w, Zone 2. A great jumble of bone from this level when sorted out represents five individuals, an adult female and four children.

(*a*) The upper limbs of the adult female were associated with each other in the burial, but the remaining skeleton was burned and scattered. One molar tooth shows an old fracture of a cusp and a small cervical carious lesion. There are no degenerative changes in the joint surfaces of vertebrae.

(*b*) Some of the fragments are those of a newborn infant.

(*c*) The skeleton of a child two to four years old has an intact skull. The elements of the temporal bone have united, a foramen in the tympanic plate is almost enclosed, but lateral growth of the plate is not complete. The condylar parts of the occipital bone have united with the squamous but not with the basilar part. All the deciduous teeth are present. The skull vault is short, broad, and high, with an almost vertical frontal region and a very flat area above the inion. The left occipital region is somewhat more prominent than the right, and both parietals bulge laterally. There is an os inca, and Wormian bones occur only in the right half of the lambdoid suture, in the parietal notch, and at the asterion. There are a large zygomaxillary tuberosity and an accessory mandibular foramen on each side.

The atlas vertebra is in four segments and the spurs enclosing the foramen transversarium are just touching. The dens segment of the axis is not united. The foramen transversarium of the third cervical vertebra is incomplete on the right, but complete and double on the left. Such double foramina occur also on the left side of C5 and bilaterally on C6. No limb epiphyses have fused.

(*d*) Some of the fragmentary remains are those of a five-year-old child. The deciduous dentition is complete, and the first permanent molar crown is well formed in its alveolus. The vertebral neural arch halves are united with each other and some have fused to their centra. The failure of fusion of the neural arches on the sacral segments at this age suggests spina bifida. No limb epiphyses have fused.

(*e*) The mandible and a few infracranial fragments of a six-year-old child displayed full deciduous dentition. The first permanent molars were almost at the occlusal plane. Accessory mandibular foramina are present bilaterally.

Tc 35w, Zone 3. This level contained fragmentary remains of the skulls and teeth of two individuals: (*a*) a 13-year-old child whose teeth showed slight attrition, and (*b*) an adult female with dentin exposed in the anterior teeth and cervical caries on a premolar.

Tc 35e, Zone B. A grave in the East Niche of El Riego Cave contained the fragmentary remains of three individuals: (*a*) an adult female, (*b*) an adult male, and (*c*) parts of the skull and teeth, burned black, of a fifteen-month-old child.

Tc 35e, Zone C. This level of the East Niche contained fragments representing two individuals: (*a*) an infant less than two years old and (*b*) an adult female with bones burned black. The front teeth of the latter are worn to expose the dentin, and the cusps of the posterior teeth are blunted. Two teeth were lost before death. One molar is carious.

Tc 50, Burial 7. This burial from Coxcatlan Cave is an adult female represented by jaws and teeth, parts of the skull which are not reconstructible, and infracranial fragments mainly of the upper limb.

The tympanic plates are slightly thickened with mar-

Table 9. Measurements of Adult Skulls, by Phase (*in mm.*)

	El Riego		Cox-catlan	Santa Maria			Venta Salada	
	Tc 50-4	Tc 50-5	Tc 272-2	Tr 218-2	Tr 218-4	Tr 218-7	Tc 35e-B	Tc 35w-C
Sex	M	F	M	M	M	M	F	M
Length	179.0	174.0	198.0*	171.0*	185.0*	168.0	–	–
Breadth	137.0	136.0	135.0*	140.0*	143.0	138.0*	–	–
Height	126.0	136.0	–	–	–	141.0*	–	–
Cranial module	147.3	148.7	–	–	–	149.0*	–	–
Cranial index	76.6	78.3	68.2	81.8*	77.3*	82.2*	–	–
Basion-nasion	102.0	97.0	–	105.0*	–	97.0	–	–
Basion-prosthion	–	99.0	–	105.0*	–	101.0	–	–
Min. frontal	86.0	85.0	88.0	96.0*	92.0	–	98.0	98.0
Length-ht. index	70.4	78.2	–	–	–	84.0*	–	–
Breadth-ht. index	92.0	100.0	–	–	–	102.1*	–	–
Bizygomatic dia.	135.0*	132.0*	–	140.0*	144.0*	138.0*	–	137.0*
Total face height	–	100.0*	–	134.0*	131.0	113.0	–	–
Facial index	–	75.8*	–	95.8*	91.0*	81.9*	–	–
Upper face height	–	60.0	–	80.0	78.0	70.0	–	68.0
Upper face index	–	45.5	–	57.1	54.2*	50.7*	–	49.6*
Nasal height	54.0	44.0	–	53.0	56.0	50.0	–	50.0
Nasal breadth	21.0	23.0	–	24.0	24.0	22.0*	–	27.0
Nasal index	38.9	52.3	–	45.3	42.9	44.0*	–	54.0
Orbital height	33.0*	38.0	–	38.0	35.0	36.0*	–	32.0
Orbital breadth	41.0*	42.0	–	40.0	40.0	42.0*	–	41.0
Orbital index	80.5*	90.5	–	95.0	87.5	85.8*	–	78.2
Alveolar breadth	–	–	–	–	62.0	–	59.0	67.0
Alveolar length	–	–	–	–	58.0	–	51.0	55.0*
Alveolar index	–	–	–	–	107.0*	–	116.0	122.0*

*Estimated.

ginal foramina but no dehiscences. There are very long mylohyoid arches on both sides of the mandible. Dentin is exposed centrally in the anterior teeth and in the lingual cusps of the maxillary molars. Many enamel pits and fissures are present on the occlusal surfaces of molars, one of which is involved in caries. These teeth show cervical caries. No degenerative changes are seen in the available joint surfaces and vertebrae.

Tc 368, Zone A. This level of Coatepec contained a few pieces of bone from two individuals, (*a*) a young child and (*b*) an adolescent.

Summary. From three sites we have the remains, most of them fragmentary, of twelve adults and ten children. Burned bone comes from three different multiple burials. In Zone 2 of the West Niche of El Riego Cave an adult female with cremated lower limbs was buried with four children, whose ages are so spaced that they could be from the same family. In the East Niche of the cave an adult male and female were buried with the burned skeleton of a fifteen-month-old child, and a cremated adult female was buried with an infant.

The teeth of the Venta Salada phase are less worn and are characterized by enamel pits and fissures. A heavy calculus deposition seems to have partially protected the teeth from caries.

The crania show signs of occipital flattening and a more oblique slope to the facial aspect of the zygoma, although the zygomaxillary tuberosity remains prominent.

The Skulls

Craniometry

With rare exceptions the crania recovered were badly damaged or fragmentary. They were reconstructed when possible, but the resulting distortion was often sufficient to make measurements invalid. Table 9 summarizes the data for the nine skulls with reliable measurements. The cranial indices fall into the mesocranic or brachycranic ranges. More recent

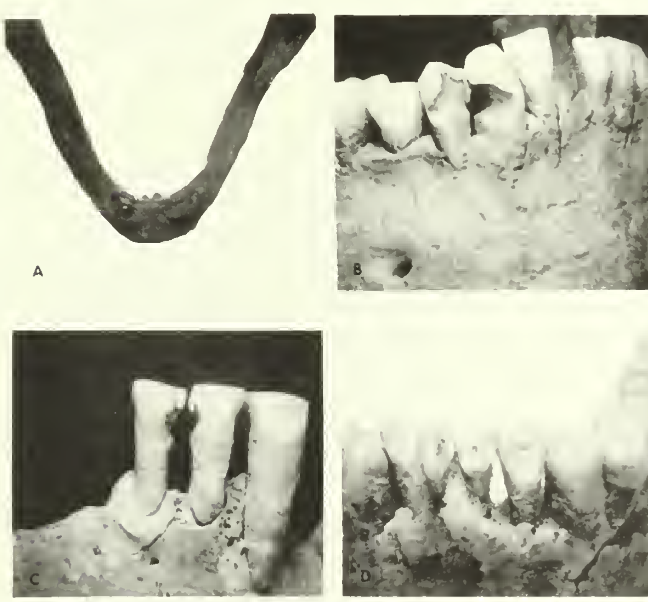

Fig. 62. *a*, Virtually toothless mandible, Tc 50, Burial 4, El Riego phase. Retained roots of both canines have exposed pulp chambers and were surrounded by abscesses. *b*, Lower right dental arch, Tc 35w, Burial B, Venta Salada phase; showing carious canine and premolar. *c*, Approximal caries of lower right premolars, Ts 204c, Burial 1, Ajalpan phase. *d*, Lower teeth, Tr 218, Burial 6, Santa Maria phase; central incisors are severely worn by a labial groove that runs downward and to the right.

Table 10. Measurements of Immature Skulls (*in mm.*)

	Venta Salada Tc 35w-L2 (2-4 years)	Palo Blanco Tc 50-1 (15 months)
Length	142.0	150.0
Breadth	149.0	130.0
Height	107.0	115.0
Cranial module	132.7	131.8
Cranial index	105.0	86.6
Basion-prosthion	71.0	69.0
Basion-nasion	72.0	78.0
Min. frontal breadth	85.0	79.0*
Length-height index	75.4	76.6
Breadth height index	71.9	88.4
Bizygomatic diameter	101.0	92.0
Total face height	79.0	69.0
Facial index	78.2	75.0
Upper face height	50.0	45.0
Upper face index	49.5	48.9
Nasal height	36.0	34.0
Nasal breadth	18.0	17.0
Nasal index	50.0	50.0
Orbital height	28.0	31.0
Orbital breadth	32.0	32.0
Orbital index	87.5	96.9
Ramus breadth	25.0	20.0
Symphysis height	21.0	18.0
Bigonial diameter	73.0	65.0
Ramus height	33.0	32.0

*Approximation.

skulls tend to be rounder headed and show a slight degree of asymmetrical occipital flattening.

The measurements of two immature skulls are given in Table 10 and photographs of their vault contour appear in Fig. 57. Tc 50, Burial 1, is longer in relation to its breadth and has a bulging occipital region which is more prominent on the left and is demarcated above by a wide supralambdoid sulcus.

Neurocranial form variations are evident in the following skulls: Tr 218, Burial 7, has a sharply sloping frontal region and an almost vertical flattened occiput. Tc 272, Burial 2, the only dolichocranic individual (cranial index 68.2), appears long and narrow as seen from above, with a very prominent occipital mound, well-marked parietal bossing, and postorbital constriction. Tc 272, Burial 4, in profile has a high lump on the parietals and a narrow occipital mound.

Morphology

The supraorbital ridges are well marked, continuous, and extend at least half way across the superior orbital margins, with which they blend. Supraorbital notches occur in 69 percent of twenty-six sides, the rest having single foramina. In one case only do the supraorbital vessels and nerve groove the surface of the frontal bone. The infraorbital foramina appear very large and in 25 percent of the skulls in which they appear have an accessory foramen supermedial to the usual site. In 26 percent the hypoglossal canal is divided by a bony partition.

The commonest shape of the nasal bones is that of an hourglass (in 87 percent of the skulls with the facial region intact) and these two bones meet each other at a rounded junction in 62 percent. The nasal bones are very narrow in the earliest skulls, but are broader in the skulls from the more recent Palo Blanco and Venta Salada horizons. Ninety-three percent have blurred subnasal margins, as shown in Fig. 54.

The facial region of young and old is distinguished by a prominent zygomaxillary tuberosity (see Fig. 54). This and the flaring of the zygoma contribute to the vertical facial profile and the straight facial contour as seen from below, all of which is well shown in the skull of Tc 50, Burial 5, illustrated in Fig. 53. This facial flatness is less prominent in more recent burials, such as the skulls shown in Fig. 54 *b* and *c*, where the zygomaxillary tuberosity is less pronounced and the facial profile is more oblique.

Of thirty tympanic plates, thickening of the lateral margin is found in 27 percent and a dehiscence in 23 percent.

The posterior pole of the skull is composed of an occipital mound in 89 percent of the sample. On the interior of the occipital bone, the groove for the superior sagittal sinus swings to the left on 25 percent of the crania.

The transverse palatine suture is either straight or bulges anteriorly, except for one specimen in which it bulges posteriorly. No torus palatinus is present.

Rarer anomalies include one os inca, two skulls with a foramen spinosum which is open medially, one unilateral occurrence of a bony spur partially dividing a foramen ovale, a precondylar facet on the anterior margin of the foramen magnum, and one ossified attachment of the apical ligament to this area. There are no examples of pterygo-basal bridging, paramastoid process, metopic suture, os japonicum, or sagittal keel.

Although the sample is hardly adequate, it suggests temporal trends toward less facial flatness, broader nasal bones, a less distinct parietal notch on the temporal bone, and the absence of tympanic-plate thickening.

The Mandibles

Table 11 summarizes four measurements taken on from four to eight male mandibles and from five to six female mandibles. As usual, the male measurements are larger than the female, but taken together, the dimensions reveal no temporal trend.

Generally the mandibles are quite robust with strong muscle markings, particularly at the angle. There is eversion of the angle in 55 percent of twenty individuals and inversion in 15 percent. Gonial eversion shows no secular trend (within the limits of the small sample, it occurs at all time levels), is not limited to males (it is found in 50 percent of the females), and is not a function of age (it is well developed in young mandibles such as that of Tr 218, Burial 5, a six year old).

In most individuals, the central part of the outer surface of the ramus is bulged or roughened. The external oblique line extending downward from the anterior border of the ramus forms a rounded torus in 71 percent of mandibles representing this area, with no significant sex, age, or time differences in its incidence. The coronoid process varies in shape in cross section. Of the sixteen mandibles with this area intact, three are triangular in cross section, eight have a sharp exterior edge, three a sharp posterior edge, and two are irregular in shape. There is no evident sex or age difference, but the triangular form occurs only in three early skeletons.

Typically in the mandibles the lower border of the body is deeply notched anterior to the prominent gonial region. This border in four mandibles is sufficiently curved to allow the bone to rock when placed on a flat surface.

Half of the mandibles have a medio-bilateral chin form. The medial form is confined to females. Of seven immature mandibles, three are medial in chin form, three are medio-bilateral, and one is bilateral. Four of the fifteen mandibles with an intact inner surface of the ramus have no projecting lingula over the mandibular foramen. This condition does not occur in the more recent skeletons. In two of the fifteen, accessory mandibular foramina are present. One of these, Tc 35w, L2:5, has one large extra foramen on the left and two smaller ones on the right. A mylohyoid arch appears in ten of thirty-eight sites (26 percent). One specimen (Tc 50, Burial 7, Fig. 59 *c*) has a bridge over a mylohyoid groove which begins at a bony aperture some distance from the mandibular foramen. There is only one example of double mental foramen, found in the fragment of an adult left mandible from Zone 6 of Tc 35w, illustrated in Fig. 59 *d*.

Table 11. Measurements of Male and Female Mandibles (*in mm.*)

	Male	Female
Minimum ramus breadth		
Range	34-40	30-37
Number	8	6
Mean	36.7	33.9
Height of symphysis		
Range	34-41	28-40
Number	4	5
Mean	38.2	33.8
Bigonial breadth		
Range	92-105	86-103
Number	6	5
Mean	100.4	95.2
Ramus height		
Range	57-72	55-65
Number	7	6
Mean	63.4	58.4

Fig. 56 illustrates the commonest appearance of Tehuacan mandibles, with gonial eversion, notching of the inferior border, and a torus on the external oblique line.

The Dentition

Crowding

The only evidences of crowding of teeth occur in four burials from the Santa Maria phase at Quachilco: Tr 218, Burials 2, 3, 4, and 6 (Fig. 62). In each case, including Burial 3 (the skeleton of a six-year-old child), there is rotation and displacement of incisors. Burial 6 also shows labial eruption and rotation of a lower canine. On the labial surface of the lower central incisors of this individual there is a deep oblique groove worn into the dentin of the crown. The presence of lip plugs in this phase suggests an explanation for this grooving, and perhaps for the incisor displacements.

Attrition

The degree and pattern of wear on the teeth fall into three quite distinct categories related to cultural phase and so reflect dietary habits.

The "early pattern" is seen in jaws from the Ajuereado, El Riego, and Coxcatlan phases. A tough fibrous

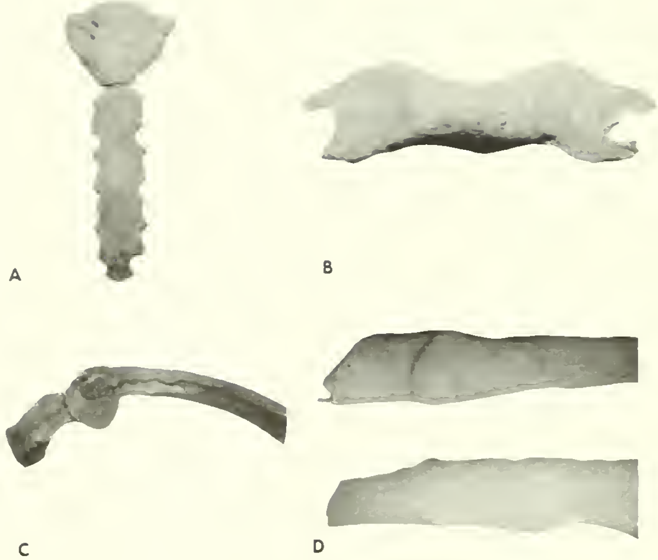

Fig. 63. *a*, Sternum, Tr 218, Burial 6, Santa Maria phase, with a large oblique bony canal passing through upper right of the anterior surface of the manubrium. *b*, Upper margin of the manubrium, Tc 272, Burial 1, Palo Blanco phase, showing irregular, notched appearance of the calcifying first costal cartilage. *c*, Under surface of a left rib, Tc 50, Burial 4, El Riego phase, showing expanded arthritic tubercle. *d*, Healed fractures of two ribs, Tc 272, Burial 2, Coxcatlan phase.

gritty diet has severely ground away the crowns of the teeth, exposing dentin and eventually the pulp chamber. The usual characteristics of the pattern are the sharply sloped, obliquely worn surfaces of the teeth, the confusing appearance of a dental arch in which each tooth slants in a different direction, and the sharp crescents of enamel remaining on the occlusal surface after the rest of the crown has been sheared away. These characteristics are illustrated in Fig. 60.

The complexity of this pattern of attrition can best be appreciated by describing the state of each tooth in one of these early skulls, for example, Tc 272, Burial 2. The only upper teeth remaining are the last four on each side of the arch and the left canine, which is worn past the cemento-enamel junction. On the right side, M3 still shows cuspal contours, but the mesiolingual cusp is worn, exposing dentin. M2 still has enamel-covered rounded buccal cusps, but the lingual half of the tooth is sharply tapered, exposing dentin all the way down to the uncovered lingual root. A crescent of enamel remains on the distal side of the occlusal surface. The tapered lingual surface formerly occluded with the buccal slope of lower M2. M1 is biconvex in the bucco-lingual plane and no enamel remains on its occlusal surface. PM2 is sharply sloped buccally, leaving only a small sharp lingual enamel crescent. On the left side of the maxillary arch, PM2 slopes buccally and all its enamel is worn away. Similarly, M1 has no remaining enamel, but it slopes lingually. M2 and M3 show much less wear. Cuspal contours are still present.

In the lower dental arch it is anterior teeth that remain, except for the tilted left M3, which is surrounded by an abscess cavity. Left M2 was present but was no longer held in its socket. The central incisors are missing, but the lateral incisors are present and are mirror images of each other, sloping sharply in the mesiobuccal plane and with a tiny, sharp distolingual enamel crescent as the last remnant of the incisive edge. Both canines have enamel crescents on their buccal margins. Two premolars remain on the left and one on the right. Their enamel is completely worn away, and both lingual and buccal surfaces are convex.

The marked degree of wear exhibited in this early pattern may be attributed to the coarse, abrasive diet of people who gathered a large part of their food from the natural vegetation, among which maguey and various cacti are prominent. The oblique occlusal surfaces sloping in various planes were the result primarily of gritty fibrous plant material being pulled obliquely through the teeth to strip away the more edible tissues. With advanced attrition, the opening of pulp chambers, and the resulting loss of teeth, the changing occlusal relationships became secondary causes of the erratic appearance of the dental pattern.

An intermediate pattern is found in the teeth of the Ajalpan phase. Generally, the degree of attrition of these full-time agriculturalists continued to be high, perhaps owing in part to the abrasive contribution of the stone mortars in which food was ground. There are no longer, however, signs of the oblique wear and projecting enamel crescents of the earlier period. Crowns of premolars and molars are worn, but worn flat. There is some evidence that anterior teeth were subjected to considerably less attrition than the grinding posterior teeth. These are characteristics usually associated with the dentition of hunting and gathering populations in other areas of the New World.

The later pattern of attrition is shared by the individuals from the Santa Maria, Palo Blanco, and Venta Salada phases—or with the dentition of most agricultural peoples. Here, the amount of wear is slight. Molar and premolar cusps are blunted by occlusal facets. Attrition is usually somewhat greater in the anterior teeth—characteristically with a thin line of dentin exposed

in the biting edge of the incisors and, in older individuals, a dot of dentin surrounded by the enamel of the blunted canine cusp.

Fig. 60 *d* is a photograph of the teeth of an adult of the Venta Salada phase showing no attrition except for small facets on some molar cusps.

Tooth Loss

Postmortem tooth loss is high in disturbed and secondary burials, particularly in Venta Salada phase skulls from both niches of El Riego Cave.

The incidence of tooth loss owing to dental pathology shows an interesting gradient in time. The number of teeth lost premortem during each phase was totaled and expressed as a percentage of the number of tooth sites in the available jaws. The accompanying tabulation shows the high incidence of tooth loss in the hunting and gathering economies decreasing with the adoption of agriculture. The dramatic decrease in tooth loss between the last two groups, both full-time agriculturists, is correlated with a significant, although not as spectacular, decrease in caries, which will be described below.

Phase	*Incidence*	*% of tooth loss*
El Riego, Coxcatlan	57/137	41.6
Ajalpan	6/16	37.5
Santa Maria	34/125	27.2
Palo Blanco, Venta Salada	8/128	6.2

As the incidence of tooth loss changes, so does its etiology. In the early phases, the causal villain was a combination of an abrasive diet and chewing habits which initiated the sequence leading through attrition, traumatic occlusion, exposure of the pulp chamber, and the introduction of micro-organisms, to the loss of the tooth from its infected alveolus. The adoption of agriculture provided a softer diet and substituted caries for attrition as the prime cause of tooth loss.

Periodontal disease, as diagnosed by porosity of the alveolar bone and recession of the alveolar margin with exposure of the roots of teeth, is more prevalent in the earlier phases. As would also be expected, the incidence of alveolar abscesses decreases with time.

Caries

It is difficult to devise a meaningful way of reporting the incidence of caries because we cannot be certain of the proportion of lost teeth that were shed because of caries. In this study, the incidence is reported as a percentage of the teeth still remaining in the mouth.

We would, of course, anticipate a rise in the caries rate with the transition to agriculture, because the high carbohydrate diet provides an encouraging environment for oral bacteria and because the softer diet produces little wear on the teeth to erase pits on the enamel surface that serve as likely sites for the beginning of caries.

When the incidence of caries is calculated for the various periods, the changing pattern shown in the accompanying tabulation is found. As expected, the teeth from early periods are rarely involved. Indeed, only two cases of caries are present in the El Riego and Coxcatlan material: one is approximal caries resulting from the traumatic impaction of food between two teeth, and the other occurs in an occlusal pit on an unopposed third molar where attrition could not eradicate a pre-carious site.

Phase	*Incidence*	*% of Caries*
El Riego	1/24	4.2
Coxcatlan	1/38	2.6
Santa Maria	15/87	17.2
Venta Salada	11/96	11.5

Although the incidence of caries does increase with the transition to agriculture, the increase is not as great as anticipated from findings on other sites, or as would be expected from the large number of enamel pits on the molar surfaces. Then too, the decrease during the Venta Salada phase calls for an explanation. The answer probably lies in the mineral-rich water of the valley, the soils of which are deposited on the teeth as a heavy calculus which effectively plugs potential carious sites. Most of the Venta Salada teeth come from El Riego Cave and have a considerably heavier calculus deposit than teeth from other sites. In preparing the specimens, the enamel pits were found only after considerable work in scaling the teeth.

The Infracranial Skeleton

Measurements

Accurate measurement was possible on relatively few limb bones because of damage to the delicate articular ends.

The formulae of Trotter and Gleser (1958) for Mongoloid skeletons were used for estimating stature. The results are summarized in Table 12. Since one of the seven females and one of the eight males for whom stature was estimated fell well outside the range of the remaining estimates, these two figures were omitted in arriving at the average statures for each sex. Heights

Table 12. Estimated Statures

	Bones Used	Stature in Cm.	Stature in Inches
FEMALE			
Tc 35w-A	Ulna	161.3 ± 4.66	63.6
Tc 35w-D	Radius	156.8 ± 4.6	61.7
Tc 35w-L2:1	Humerus	160.1 ± 4.25	63.0
Tc 35e-B:I	Humerus	156.1 ± 4.25	61.4
Tc 50-5	Fibula	159.4 ± 3.24	62.8
Tc 272-1	Fibula	157.4 ± 3.24	62.1
Tc 272-4	Ulna	167.8 ± 4.66	66.0
MALE			
Tc 35w-C	Femur and fibula	163.8 ± 3.18	64.5
Tc 35w-E	Radius	166.3 ± 4.60	65.5
Tc 50-4	Tibia	165.1 ± 3.27	65.0
Tr 218-2	Fibula	157.3 ± 3.24	62.0
Tr 218-4	Tibia	171.8 ± 3.27	67.7
Tr 218-7	Radius	165.5 ± 4.60	65.2
Tr 218-8	Radius	168.8 ± 4.60	66.4
Tc 272-2	Femur	168.8 ± 3.80	66.4

for the remaining six females ranged between 156.1 and 161.3 cm. and averaged 158.5 cm., or 62.4 inches. The seven male statures ranged between 163.8 and 171.8 cm. and averaged 167.2 cm., or 65.8 inches. If the estimated statures of Tc 272, Burial 4, and Tr 218, Burial 2, are included—the first being a rather tall female and the second a very short male—the average for each sex comes out the same, 166.0 cm., or 65.3 inches.

A low intermembral index of 66 indicates that the legs are rather long in proportion to the upper limbs. The brachial index is high, ranging from 74 to 80, indicating a relatively long forearm. For this index, Comas (1960) reports a range of 73.2 to 74.5 in Europeans and 76.9 to 78.2 in American Indians. The crural index of approximately 87 indicates a relatively short femur in relation to tibial length.

Platycnemic indices reflect the minimal amount of tibial shaft flattening present. Values range from 58.7 to 74.2, with a mean of 67.1. Indices below 63.0 are considered platycnemic. Platymeric indices range from 71.9 to 96.0. A gradual increase in this index with time shows a tendency to reduction in the degree of femoral shaft flattening. The mean for the El Riego period is 75.0, for the Santa Maria period 78.5, and for the Venta Salada period 82.2.

The length of the diaphyses of immature skeletons was measured to aid in determining age. These figures are given in Table 13.

Morphology

This section summarizes the incidence of certain variations in the bones of the infracranial skeleton.

The scapulae typically have a convex medial border, a blunt inferior angle, a rectangular acromion, and a supraspinous part that forms a low triangle. They also have a suprascapular notch, fairly deep in individuals from the earlier levels and almost indiscernable in those of the Venta Salada period.

A septal aperture is present in about half of the female humeri but never in the male humeri. There are no cases of third trochanter of the femur or vastus notch on the patella. The so-called squatting facets are neither so common nor so prominent as in most series of American Indian tali. In half of the individuals the anterior and middle talar facets on the calcaneus are joined.

Of eleven intact atlas vertebrae, three have bilateral anomalous foramina in the posterior arch, and two have a bridge over the vertebral artery. There are a few examples of double foramen transversarium, but damage has reduced the number of intact cervical vertebrae to an insufficient sample. Two vertebral columns have accessory articular facets between L5 and S1. Both individuals come from the Santa Maria level at Quachilco.

Pathology

Pathological specimens from the Tehuacan sites may be classified into four categories: trauma, infections, degenerations, and congenital abnormalities.

Trauma

The skeletons of twenty-one adults are sufficiently complete to determine the presence or absence of injury to all of the body parts. Of these, five show evidence of healed fractures of a total of eighteen bones: one scapular body, shafts of two radii and one ulna, one fibular shaft, one fifth metatarsal, five ribs, and seven vertebrae.

Table 13. Length of Immature Diaphyses (*in mm.*)

	Tc 50-2 (5 yrs.)	Tc 50-3 (under 6 mos.)	Tc 50-6 (under 6 mos.)	Tc 35w-L2 (2-4 yrs.)	Tc 35w-L2 (5 yrs.)	Tr 218-3 (8 yrs.)	Ts 368-3 (24 mos.)
Clavicle	81	48	43	63	–	–	–
Humerus	148	69	62	108	130	167	–
Radius	–	56	–	83	104	129	88
Ulna	–	64	59	93	114	145	95
Femur	199	78	75	141	167	228	–
Tibia	166	67	60	117	140	–	117
Fibula	160	63	–	113	138	188	–

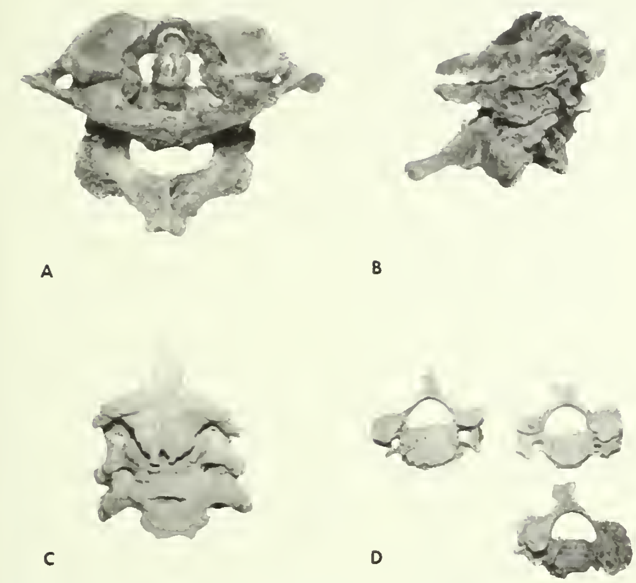

Fig. 64. *a*, Arthritic lipping of the dens facet of the atlas and a fan-shaped exostosis of the apex of the dens, Tc 50, Burial 4. *b*, C5–7 from the same burial, showing advanced arthritic involvement of the apophyseal joints. *c*, Segment of the cervical vertebral column, Tr 218, Burial 2. Large osteophytes project downward from the front of the body of the axis. C3 and C4 are fused. *d*, Advanced arthritis and osteophytosis of three cervical vertebrae, Tc 50, Burial 5. Lipping from the uncovertebral joint encroaches on the foramen transversarium and on the left side of the fifth vertebra completely occludes it.

Of the five skeletons from the two earliest phases represented (El Riego and Coxcatlan), four have healed fractures: Tc 272, Burial 4, Colles' fracture of the left radius (Fig. 68 *b*); Tc 272, Burial 2, two ribs (Fig. 63 *d*); Tc 50, Burial 4, a wedge-shaped compression fracture of the third thoracic vertebra (Fig. 65 *c*) and fractures of the fifth metatarsal and shafts of the left radius and ulna (Fig. 68 *a*); Tc 50, Burial 5, the left scapula (Fig. 67), three ribs, and six vertebrae, two of which have wedge deformities (Fig. 65 *d*).

In contrast, only one fracture (a left fibular shaft in Tc 35w, Burial E) appears in the sixteen adult skeletons from the three later phases: Santa Maria, Palo Blanco, and Venta Salada.

The marked decrease in evidences of trauma no doubt reflects the adoption of a settled way of life and an easier one. It should be noted that among the many fractures of the earlier periods none is of a lower-limb long bone; a person with such an injury probably would not have made it back to the cave.

Infection

The high incidence of mandibular abscesses following exposure of the chamber in severely worn teeth has already been described.

The most spectacular result of infection in this collection is the eroded skull of Tr 218, Burial 2—the result of treponematosis (Fig. 58 *c* and *d*). The compound nature of the fractured scapula of Tc 50, Burial 5, is confirmed by the multiple areas of infection along the fracture lines. One further evidence of infection is the slight periostitis of the tibial shaft in Tc 35w, Burial B.

Degeneration

Degenerative joint disease is evident in a very high percentage of the adult Tehuacan skeletons. Osteophytosis of the vertebral bodies is present in ten of fourteen intact columns, seven showing advanced stages of the process (Fig. 64). Of these, four have involvement of the apophyseal joints. In Tc 50, Burial 5, arthritic lipping has encroached upon the foramen transversarium of cervical vertebrae with resulting occlusion of the vertebral artery on one side.

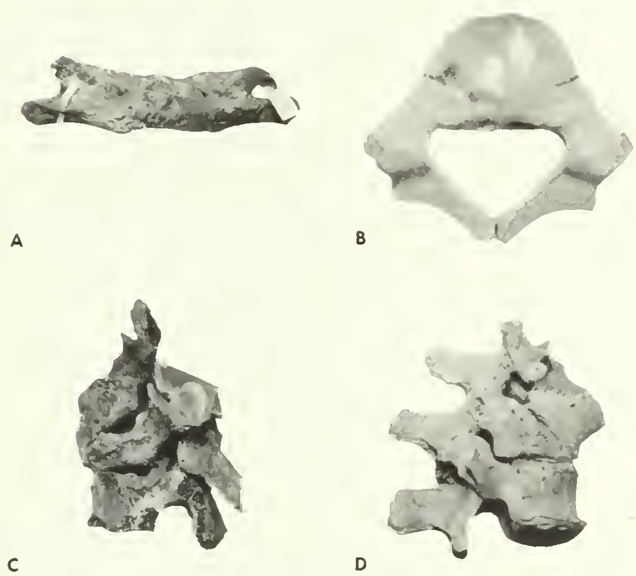

Fig. 65. *a*, Atlas, Tr 218, Burial 4, seen from behind. The marker at left is in an anomalous posterior arch foramen; on the right, an incomplete lateral bridge over the vertebral artery. *b*, L5 of Tc 50, Burial 2, a 5-year-old child. The neural arches have failed to fuse on this and L4 and on all of the sacral segments: a case of spina bifida. *c*, Compression fracture of T3, Tc 50, Burial 4; an osteophyte has fused its body anteriorly to the vertebra above. *d*, Compression fracture of T12, Tc 50, Burial 5.

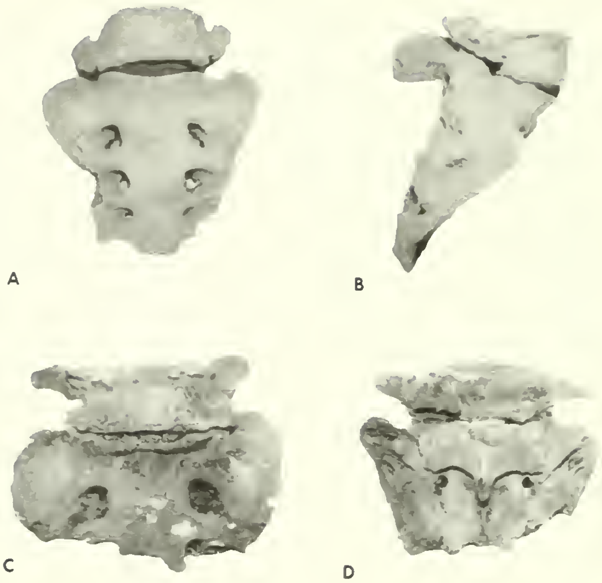

Fig. 66. *a*, Front of L5 and sacrum, Tr 218, Burial 4. The sacrum has only four elements and there are only five lumbar vertebrae. *b*, Side view of L5 and sacrum, Tr 218, Burial 7. Both specimens show accessory articular facets. *c*, Anterior and, *d*, posterior views of the lumbosacral region, Tc 50, Burial 4. There is spondylolisthesis of L5.

Eleven of nineteen adult skeletons show the lipping, erosion, and eburnation of osteoarthritis in some or all of the joints. Examples are illustrated in Figs. 63 and 69.

Congenital Abnormalities

Abnormalities sufficiently severe to be considered pathological appear in three skeletons. Tc 35w, Burial D, had bilateral congenital hip dislocation shown by the shallow acetabulum with deficient margin (Fig. 69 *a*). Spondylolisthesis of the fifth lumbar vertebra is evident in Burial 4 of Tc 50 (Fig. 66 *c*). Spina bifida of the last two lumbar and all of the sacral vertebrae is evident in Burial 2 of Tc 50 (Fig. 65 *b*).

Comparisons

In comparing the Tehuacan material with that of other sites, we would hope to answer four questions: How do the earlier Tehuacan skeletons differ from those of recent American Indians? Do they resemble recent Mexican material more than other New World groups? Is there similarity between specimens of early man from various localities in the Americas? Do distant affinities show in comparison with Asian skeletons of the same time level? It is disappointing that answers to these questions cannot yet be found. There are few sites from which skeletons of early man have been recovered. The Tehuacan series, because of its size, condition, and long span of time, cannot produce valid metrical data, although the more important morphological observations are available for comparison. Unfortunately, however, very little morphological description has been published for the more recent osteological populations, although metrical data are available. A preliminary survey of some of the comparative material will at least set the stage for future attempts to answer these questions.

Because of its Mexican location and probable antiquity, it is natural that our first comparisons should be with Tepexpan man (De Terra *et al.* 1949). The accompanying tabulation lists the measurements in millimeters of the Tepexpan skull and an early male skull from Tehuacan, Tc 50, Burial 4 (El Riego phase). The two are very similar metrically differing chiefly in the somewhat smaller size of Tc 50, Burial 4, and in the broader nasal region of Tepexpan, in which it resembles some of the more recent Tehuacan skulls. Neither has a sagittal keel, and both have heavy V-shaped supraorbital ridges and a mound-shaped occipital region. Dental conditions make it impossible to estimate facial height and the degree of prognathism. In both, the nasal bones appear pinched and the inferior nasal margin is indistinctly demarcated from the face.

	Tepexpan	*Tc 50–4*
Cranial length	179.0	179.0
Cranial breadth	143.0	137.0
Basion-bregma	136.0	126.0
Cranial module	152.6	147.3
Cranial index	79.9	76.6
Length-height index	76.0	70.4
Breadth-height index	95.1	92.0
Minimum frontal breadth	99.0	86.0
Bizygomatic diameter	140.0°	135.0°
Orbital height	34.0	33.0°
Orbital breadth	40.0	41.0°
Orbital index	85.0	80.5°
Nasal height	49.0	54.0
Nasal breadth	25.0	21.0
Nasal index	51.0	38.9
Ramus breadth	36.0	36.0
Ramus height	—	58.0
Bigonial diameter	104.0°	92.0

° Estimated.

Both have prominent zygomaxillary and malar tuberosities and a vertical profile of the lateral face. The mandibles are similar, with low, broad ramus, gonial eversion, a notched inferior border of the body, and a prominent external oblique line. Neither has a palatine or mandibular torus.

Although there has been considerable tooth loss and alveolar resorption in Tepexpan man, the remaining teeth show the advanced oblique attrition with occlusal enamel crescents which is characteristic of the early Tehuacan teeth.

Similar dental conditions are found in the cranial material from Santa Maria Astahuacan (Romano 1955), which has a radiocarbon date of 9670 B.P. ± 400 years. A single mandible has lost a third molar and both central incisors. Four teeth have sharp lingual enamel crescents, while on the left first premolar attrition has removed all the enamel and exposed the pulp chamber. As in the Tehuacan specimens, oblique wear varies in its plane from tooth to tooth: buccal, distal, distolingual, and mesiolabial.

A male skull from the same site resembles Tc 50, Burial 4, in having V-shaped brow ridges, an occipital mound, gonial eversion, and a blurred subnasal margin. It differs, however, in its slight sagittal keel and in the absence of the characteristic facial flatness. There is no metopic suture, mylohyoid arches, or multiple foramina, but there is a dehiscence in each tympanic plate.

Table 14 compares five metrical indices of certain skulls from the New World to which considerable antiquity has been ascribed. Metrically, the skull of Tc 50, Burial 4, resembles Tepexpan and Sauk Valley more closely than the others. The skull of Brown's Valley Man from Minnesota (Jenks 1937) is longer and higher, with a broader nasal region and taller orbits. Although there is slight gonial eversion, in most respects the mandible does not resemble the Tehuacan pattern in that it has a tall narrow ramus and there is no thicken-

Table 14. Comparative Data on New World Skulls (*in mm.*)

	Cranial index	Length-height index	Breadth-height index	Nasal index	Orbital index
Tehuacan Tc 50-4	76.6	70.4	92.0	38.9	80.5
Tepexpan	79.9	75.9	95.1	51.0	85.0
Brown's Valley	73.5	73.6	100.0	46.5	92.8
Confins	69.2	80.0	114.0	48.9	94.2
Sauk Valley	74.2	73.3	98.6	46.5	80.5
Punin	71.0	66.0	94.0	59.6	69.2
Lagoa Santa	70.7	74.3	104.7	50.7	86.4

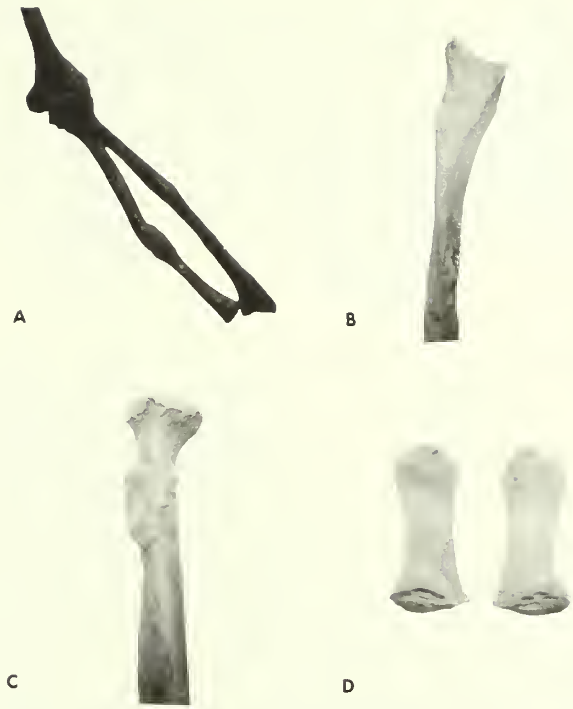
A B C D

Fig. 68. *a*, Healed fractures of midshaft of left radius and ulna, with angulation and considerable callus formation, Tc 50, Burial 4. *b*, Healed Colles' fracture of left radius, Tc 272, Burial 4. *c*, Osteophytosis of bicipital tuberosity of left radius of Tc 50, Burial 5. *d*, Pseudoepiphyses of both first metacarpals in a child, Tc 50.


A B C D

Fig. 67. Healed fracture of the body of the left scapula, Tc 50, Burial 5. The dorsal *a*, and costal surfaces, *b*, show the triradiate fracture line, central defect, and multiple abscess holes. *c*, Involvement of the lower part of the glenoid fossa and growth of osteophytes into the triceps tendon. *d*, The underlying three ribs show healed fractures. See also Fig. 64, *d*.

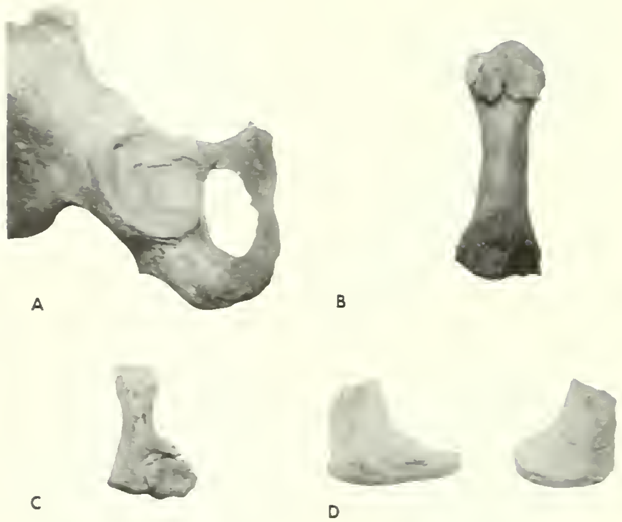

Fig. 69. *a*, Right acetabulum, Tc 35w, Burial D, is elongated, shallow, and has a deficient anterior margin; the condition is bilateral. *b*, Lipped and eburnated head of first metatarsal, Tc 50, Burial 5. *c*, Middle phalanx of left third finger of the same burial, lipped proximally to accept an sccessory ossicle. *d*, Trapezoids, Tr 218, Burial 4; at left, the "toe of the boot" is extended by a porous osteophyte.

ing of the external oblique line or notching of its inferior border. The subnasal margin is sharp. Confins man (Walter *et al.* 1937), which was discovered a few miles from Lagoa Santa in Brazil, differs in having a longer and higher vault, a broader nasal region, and almost square orbits. An examination of the published photographs, however, revealed certain morphological similarities to the Tehuacan material: a prominent zygomaxillary tuberosity, vertical malars flattened coronally, and a mandible with short broad ramus and gonial eversion. Subnasal prognathism is spectacular. Except in the anterior teeth, attrition is not far advanced.

The Punin Calvarium (Sullivan and Hellman 1925) from central Ecuador differs greatly from Tehuacan, not only in its longer vault, broader nasal region, and low rectangular orbits, but in its scaphoid vault and the absence of malar verticality. The Sauk Valley skull (Jenks and Wilford 1938), although similar to Tehuacan in the indices reported, differs in showing marked postorbital constriction, a more acute frontal slope, a slight sagittal crest, and a much taller mandibular ramus (71.5 mm. vs. 58.0 mm. in Tehuacan).

During the excavation of the El Risco site in the Valley of Mexico (Mayer-Oakes 1959) a complete skeleton was recovered, a report of which has not yet been published. The cultural context is the early Postclassic period, with a date of approximately A.D. 800. Because of certain similarities to the Tehuacan material, it will be described briefly here.

The skeleton is that of a twenty-five-year-old female. Its stature of 158.1 ± 3.24 cm. places it within the range of Tehuacan females. Limb proportions are as in the Tehuacan skeletons: a relatively long forearm (brachial index, 79.6), short femur (craral index, 68.2), and long legs in relation to upper limbs (intermembral index 68.2). There is no flattening of the tibial shaft (platycnemic index 70.0), but the femoral flattening is shown in a platymeric index of 74.3.

	El Risco	*Tehuacan Tc 50–5*
Cranial length	172.0	174.0
Cranial breadth	139.0	136.0
Basion-bregma	134.0	136.0
Cranial module	148.4	148.7
Cranial index	80.8	78.3
Length/Height index	77.8	78.2
Breadth/Height index	96.4	100.0
Minimum frontal breadth	84.0	85.0
Bizygomatic diameter	129.0*	132.0*
Orbital height	33.0	38.0
Orbital breadth	39.0	42.0
Orbital index	84.7	90.5
Nasal height	50.0	44.0
Nasal breadth	26.0	23.0
Nasal index	52.0	52.3
Ramus height	66.0	60.0*
Ramus breadth	37.0	37.0
Symphysis height	37.0	31.0*
Bigonial diameter	93.0	101.0

*Estimated.

The close craniometric similarity is illustrated in the accompanying tabulation, which compares El Risco with the female skull from Burial 5 of Tc 50, an El Riego phase skeleton. Measurements are in millimeters. Morphologically, El Risco shows the following similarities: V-shaped supraorbital ridges, an occipital mound, blurred subnasal margins, a thickened tympanic plate, and a rather flat malar region. The Tehuacan mandibular pattern is also present, with a short, broad ramus, a torus on the external oblique line, a notched inferior border, and gonial eversion. It differs in its very wide nasal bones, a somwhat scaphoid vault, and in the absence of a zygomaxillary tuberosity. There is considerable alveolar prognathism. Attrition has flattened the occlusal surface of the teeth, exposing dentin in the base of the cusps.

Among New World populations outside of Mexico, the Tehuacan morphological complex is found most closely, strangely enough, among the Eskimo. Of nine qualities listed as characteristic of Eskimo (Oschinsky 1964), six are typical of the earliest skulls from Tehuacan: narrow nasal bones, vertical malars, thick tympanic plate, gonial eversion, short broad ramus, and concavo-straight inferior margin of mandible. Eskimo characteristics not seen in the Tehuacan skulls are: sagittal keel, palatine torus, and mandibular torus. Although there is considerable similarity in the morphology of the face, mandible, and temporal bone, Eskimo crania are considerably larger, longer, and more rugged than those from Tehuacan.

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CHAPTER 7

Codex Borgia and the Venta Salada Phase

Robert Chadwick and Richard S. MacNeish

Archaeological surveys of the area bordering the Tehuacan Valley demonstrate the existence of remains of the terminal aboriginal culture, known archaeologically as the Venta Salada phase, within a rather well-defined region that is approximately coterminous with the pre-Conquest domain of the Señorio de Teotitlan del Camino, an independent political enclave within the Aztec empire. For this reason, we assume that documentary information about the people of the Tehuacan Valley and the Señorio de Teotitlan may supplement our knowledge of the Venta Salada phase.

Despite the importance of the area both politically and ceremonially at the time of the Conquest, documentary material dealing directly with Tehuacan or the Señorio is scant (Nicholson 1955: 117). The valley was not the subject of intensive ethnographic investigations such as those conducted by Burgoa in Oaxaca or by Sahagún in the Valley of Mexico. Some information about the region can, however, be garnered from such sixteenth-century sources as Ixtlilxóchitl, Torquemada, Motolinia, Román y Zamora, Herrera, and the *Relaciones geográficas* of Coxcatlan and of Teotitlan del Camino. Twentieth-century studies by Eduard Seler, Francisco del Paso y Troncoso, Joaquín Paredes Colín, Gorgonio Gil, Robert H. Barlow, Carmen Cook de Leonard, Eduardo Noguera, Henry B. Nicholson, and Alfonso Caso have brought to light data that bear upon the ancient history of the Tehuacan Valley.

Better for our purposes than either ancient or modern secondary sources are the pictorial manuscripts or "codices" dealing with history and religion that were painted by the Indians themselves. Many indigenous peoples of Mexico, among them the Aztecs, Mayas, Zapotecs, and Mixtecs, painted such books in late pre-Hispanic times, or during the years immediately following the Spanish conquest. Some of the latter bear comments written in Spanish or Nahuatl to explain the pictures.

A few of these folding books have, for reasons of content or style, been linked by some scholars with that part of Mexico in which the Tehuacan Valley lies and at least one has been linked with the Tehuacan Valley itself (Seler 1963: 101–103). The relevant books consist of six manuscripts dealing with ritual calendrical matters which have been called "the Borgia group" because the Borgia Codex is chief among them. The other five are the codices Laud, Fejérváry-Mayer, Cospi, Vaticanus 3773, and Mexican Manuscript Number 20 of the Bibliotèque Nationale in Paris (Robertson 1966: 298). The reverse of Codex Porfirio Díaz has been placed in the same group by Nicholson (in press). Besides a common hieroglyphic system and a common concern with ritual matters, a distinctive graphic style —shared with a group of genealogical and historical codices of acknowledged Mixtec derivation—has provided grounds for classifying these manuscripts together and for attributing to them a Mixtec origin (Robertson 1966: 309).

During a perusal of the codices of the Borgia group we noted that pottery vessels depicted in Codex Borgia are similar to types characteristic of the Venta Salada phase. Further, most of the depicted Venta Salada pottery types occur in the general region of the Señorio de Teotitlan, and are characteristic of that region and cultural phase. They do not occur farther south in the

contemporaneous Monte Alban V ceramic complex in Oaxaca, or to the north in Cholulteca I-III of Puebla and adjacent Tlaxcala, or in Aztec periods of the Valley of Mexico. Such pottery types have not been discovered east of the Tehuacan Valley in such cultural manifestations as Cempoala I-IV, Isla de los Sacrificios, or Upper Cerro de las Mesas in Veracruz. No excavations have yet been carried on to the west of the Tehuacan Valley.

Accordingly, we began a comparison of material items depicted in Codex Borgia and artifacts representative of the material culture of the Venta Salada phase. As a result, we have come to the conclusion that the Borgia and the Venta Salada phase are closely related. It seems probable that Codex Borgia originated in the Señorio de Teotitlan, with the culture characterized as the Venta Salada phase, and quite possibly within the Tehuacan Valley itself. If our assumptions are correct, the scant documentary information concerning the Venta Salada phase can be augmented by data derived from one of the most ornate and complete prehistoric religious documents of central Mexico—Codex Borgia.

Before we present the evidence for connecting Codex Borgia with the Venta Salada culture of the Tehuacan region, we should say a few words about the codex itself. The earliest knowledge concerning it dates from the late eighteenth century, when it was owned by Stephano Cardinal Borgia in Veletri, Italy. Through him, it came to the Library for the Propagation of the Faith in Rome. Details of the manuscript were first published by Baron von Humboldt in 1813 and its first edition was by Lord Kingsborough in 1830. The first truly important study of the document was undertaken by the German scholar Eduard Seler (1904-1909). Recent scholars, including Caso, Nicholson, Robertson, and others, have added further to the analysis of the codex.

The Borgia manuscript is painted on both sides of a strip of animal hide, probably deerskin, made of fourteen separate pieces giving a total length of about ten meters and folded into thirty-nine leaves each 26.5 by 27.0 centimeters (Lehmann 1905: 251). The codex is for the most part a book of rituals and ceremonies and probably served as a manual for priests and diviners (Nicholson: in press). Although its glyphs have been deciphered, some of its complex ritual scenes have not yet been fully interpreted. The codex itself (CB 1963) and a Spanish translation of Seler's original commentary (Seler 1963) have recently been published in Mexico.

Various authors have speculated as to its place of

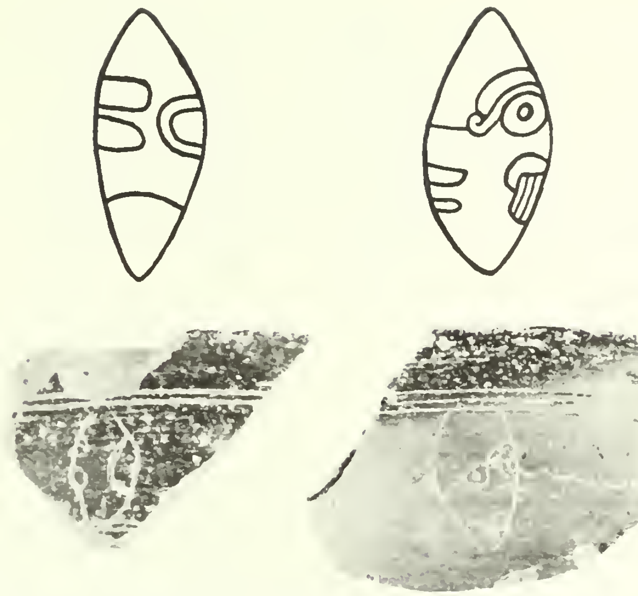

Fig. 70. Variations of the glyph Flint Knife from Codex Borgia, pls. 2 and 15, and similar glyphs on sherds of Teotitlan Incised pottery from an important Venta Salada site.

origin. Seler first thought that it derived from the Gulf Coast but later came to believe that it was painted in the area of Tehuacan-Coxcatlan-Teotitlan del Camino. Caso, struck by similarities between the Borgia and altar paintings discovered at Tizatlan, Tlaxcala—particularly a representation of the god Tezcatlipoca—was convinced of a Tlaxcala-Puebla origin. Cholula receives strong support from other authors, and still others point to the Gulf Coast as a possible provenience. We believe that the strongest arguments are those supporting a Mixtec attribution, but to review all the evidence for or against the various theories is beyond the scope of this paper. Our major purpose is to point out the observations that have brought us to believe that Codex Borgia was painted by people whose material culture conforms to the Venta Salada phase within the area of distribution of that culture, the Señorio of Teotitlan del Camino, in which the Tehuacan Valley is included.

A glyph for Flint Knife engraved on a potsherd from a large Venta Salada site (Tr 75) near Tilapa constitutes significant evidence of a close connection between Codex Borgia and the Venta Salada phase of the Tehuacan cultural sequence. The symbol engraved on this sherd (Fig. 70, left) is identical to one used throughout the codex and featured as the central ornament on the breast of the god Tezcatlipoca in Borgia plate 17. Although codices of the Borgia group and the Mixtec genealogical codices indicate the day Flint

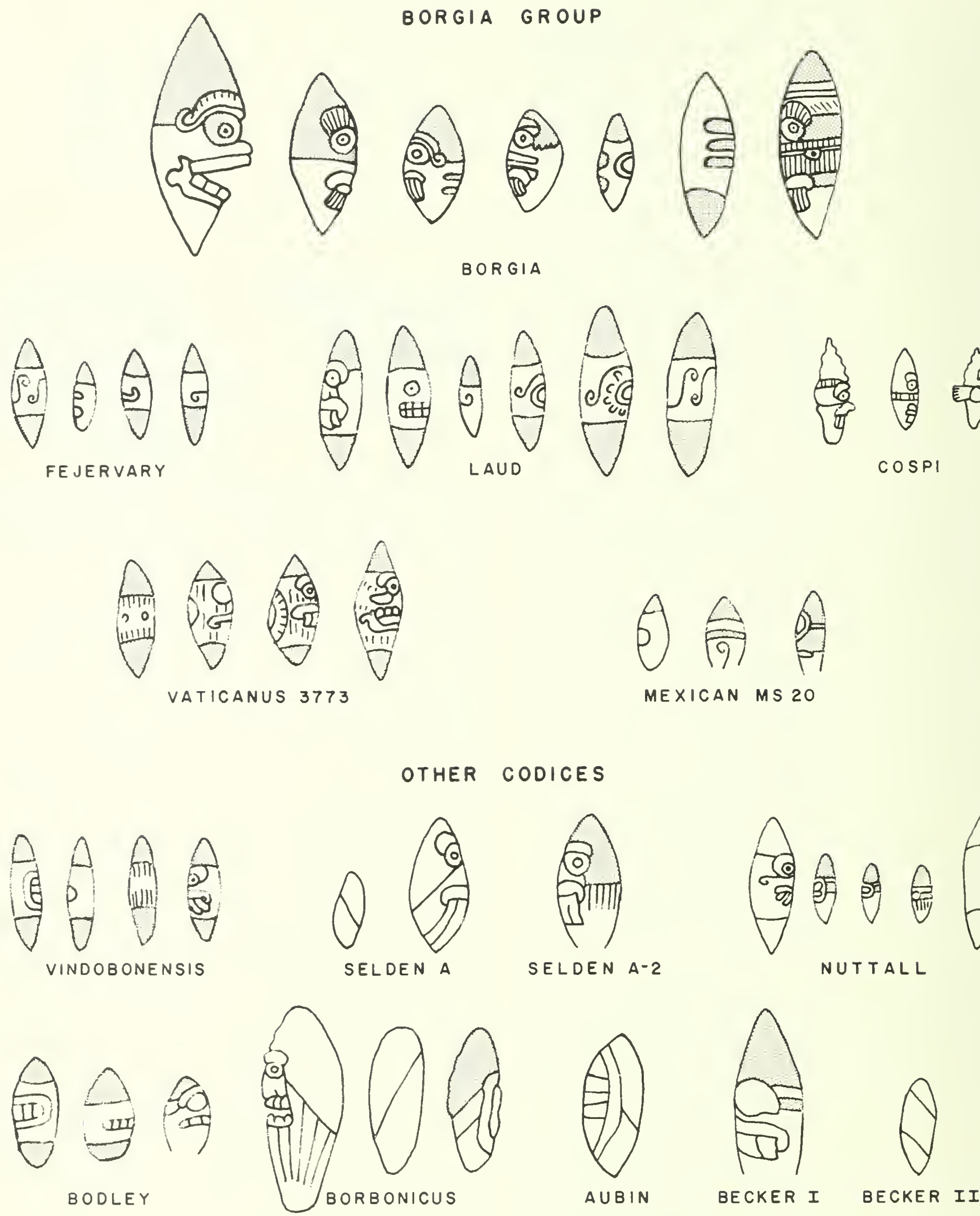

Fig. 71. Glyphs for Flint Knife from various codices.

Knife by a number of variations of the glyph, all displaying a general resemblance but differing greatly in detail, this particular form can be found only in Codex Borgia. A second sherd from the same Venta Salada site (Fig. 70, right) also is engraved with a glyph. This glyph resembles somewhat another Flint symbol in the Borgia but is perhaps closer to variations appearing in Codex Laud and illustrated in Fig. 71, together with glyphs from several related codices.

Another indication that the Borgia may have been painted in the area of Venta Salada culture is the probable date symbol on the sculptured stone *temalacatl*, or gladiatorial stone, from Tehuacan, now in the regional museum in Puebla. This large stone undoubtedly came from a site on Cerro de la Mesa, north of town. It bears a "ray" symbol that in form closely resembles the year symbol in Codex Borgia (pls. 27, 28, 51, 52, 71), which is the only manuscript of the Borgia group to show this particular symbol (Nicholson: in press). The symbol differs from the usual "A-O" version of the Mixteca in that it lacks the "O" element interlacing the "A" or "ray" element. According to Nicholson, this rendition also resembles early forms of the symbol found at Teotihuacan, Texmelincan, and occasionally, Monte Alban. The similarity between the representation of this symbol on a sculpture from a Venta Salada site and representations of the same symbol in Codex Borgia suggests a close relationship between the manuscript and the Tehuacan Valley.

Other Venta Salada artifacts, of which the most convincing are various pottery types, also provide evidence of a connection between the Venta Salada phase and Codex Borgia. The diagnostic Venta Salada pottery type, Teotitlan Incised, seems to be dominant among pottery forms depicted in Codex Borgia. According to present archaeological evidence, this pottery is not a resident type outside the region of the former Señorio de Teotitlan del Camino. It has not been recorded for Cholula in central Puebla, Cempoala in central Veracruz, or Monte Alban V in Oaxaca. The most common decoration of Teotitlan Incised consists of two or three straight parallel lines forming a horizontal band. Often two sets of horizontal parallel lines separated by vertical lines form rectangles. Sometimes, instead of vertical lines, diagonal lines divide the bands into diamonds or triangles. One or more small carved circles, squares, or spirals appear in about half the areas so delimited. The circle in a rectangle or diamond drawn with double lines is the most common decoration on the Borgia pots. In a few instances, in both the Borgia and Teotitlan Incised, a band of "U" elements, lying horizontally, is placed between the band of rectangles and the rim of the vessel. In a very few cases the incised element consists of a stepped design filled with crosshatching.

The double-outlined rectangles or triangles, usually with a circle in the center, are also used in other ways in the codex: in plates 12–19, 24–26, 51, 55–59, 61–72, and 76 as part of the decorative devices on garments; in plate 21 as part of the decoration of a ball-court marker; in plates 23, 40, and 71 in solar disks: in plates 25, 60, 64, 71, and 76 in shields; in plate 49 in a tree; and in plates 51, 55, and 56 on staffs. Although this inventory is by no means exhaustive, its importance lies in the fact that dominant elements of design on the ceramic type, Teotitlan Incised, are also among the most popular designs in Codex Borgia.

These designs in the Borgia appear on pots of two colors—yellow-brown and gray, the colors of Teotitlan Incised, although this type is more streaky black than gray. Thus the close connection between the Borgia pots and archaeological pottery of the type Teotitlan Incised is demonstrated by the use not only of similar decorative elements but also of similar colors.

The correspondence between the forms of vessels shown in the Borgia Codex and those of archaeological examples of Teotitlan Incised from the Venta Salada phase is remarkably close. These similarities are seen in the range of forms and appendages and the relative frequency of each. The most popular form of Teotitlan Incised vessel, both in archaeological examples and in Borgia drawings, is a tripod flat-bottomed bowl with outflaring walls. Hemispherical bowls or cups are relatively rare, and flat-bottomed, flaring-necked ollas with two loop handles are extremely rare.

Some types of vessel supports shown in the codex —stepped, animal head, and dumbbell or "bulb"—are identical with three styles found in the pottery of the Venta Salada phase. A preliminary survey shows that this inventory of vessel supports is seen only in the Borgia Codex and in no other.

The ceramic type Coxcatlan Red, occurring as flat-bottomed bowls with distinctive stepped feet and vertical to slightly flaring walls, may be seen on Borgia plates 8 and 60. Red wares with stepped feet are not to our knowledge found outside the Venta Salada culture province.

Among the more common pottery types in Codex Borgia is one in which "V" elements decorate a vessel of tall cylindrical form (pls. 6 and 18). We believe the V's represent the conical appliqué of Coxcatlan Coarse, a type in which large cylindrical vessel forms are common. The codex also shows this type with spherical feet (pls. 11, 14, 23, 63, and 65). Examples of this pot-

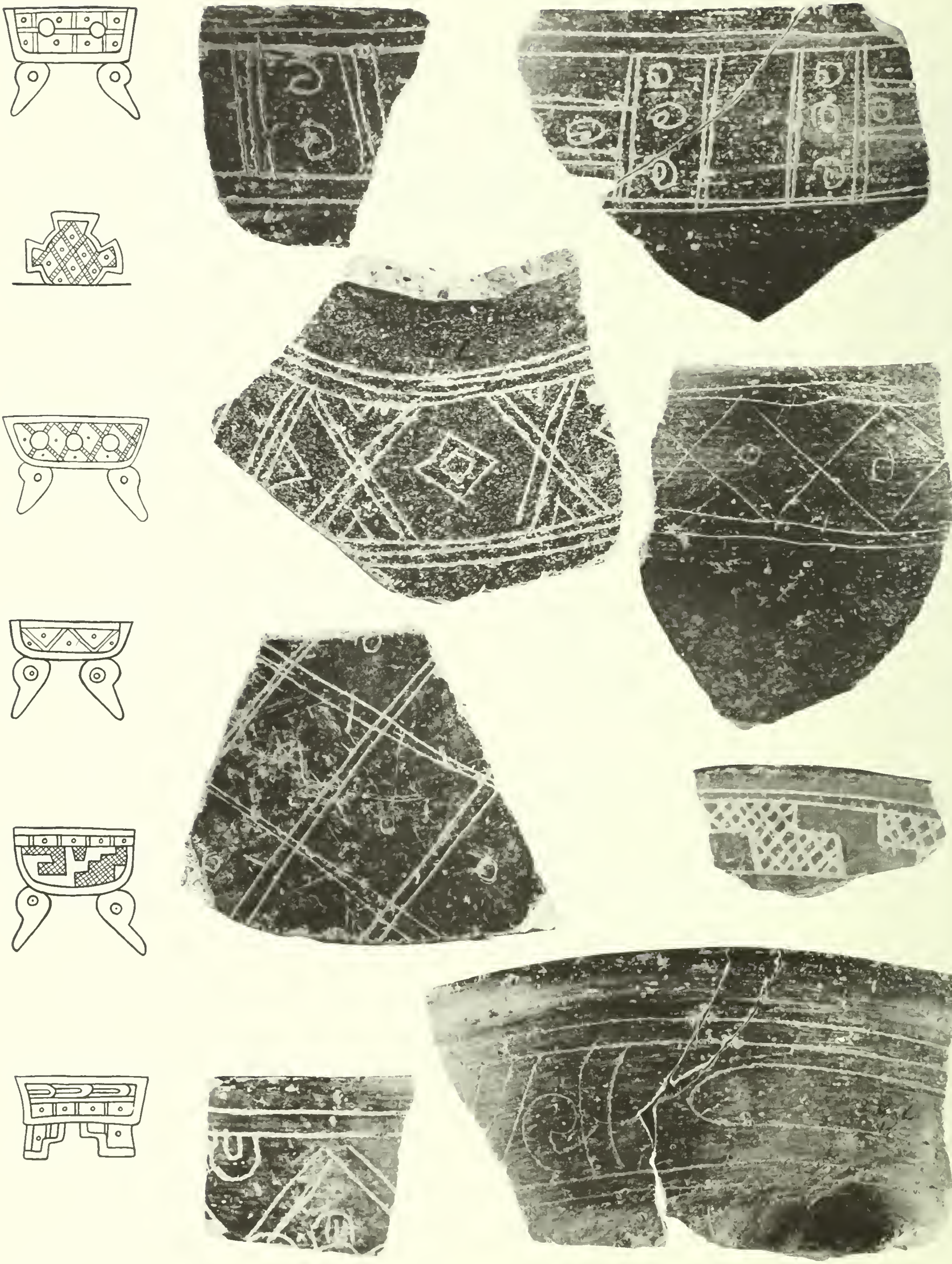

Fig. 72. Sherds of Teotitlan Incised and vessels from Codex Borgia, pls. 3, 4, 70, 67, 69, 65.

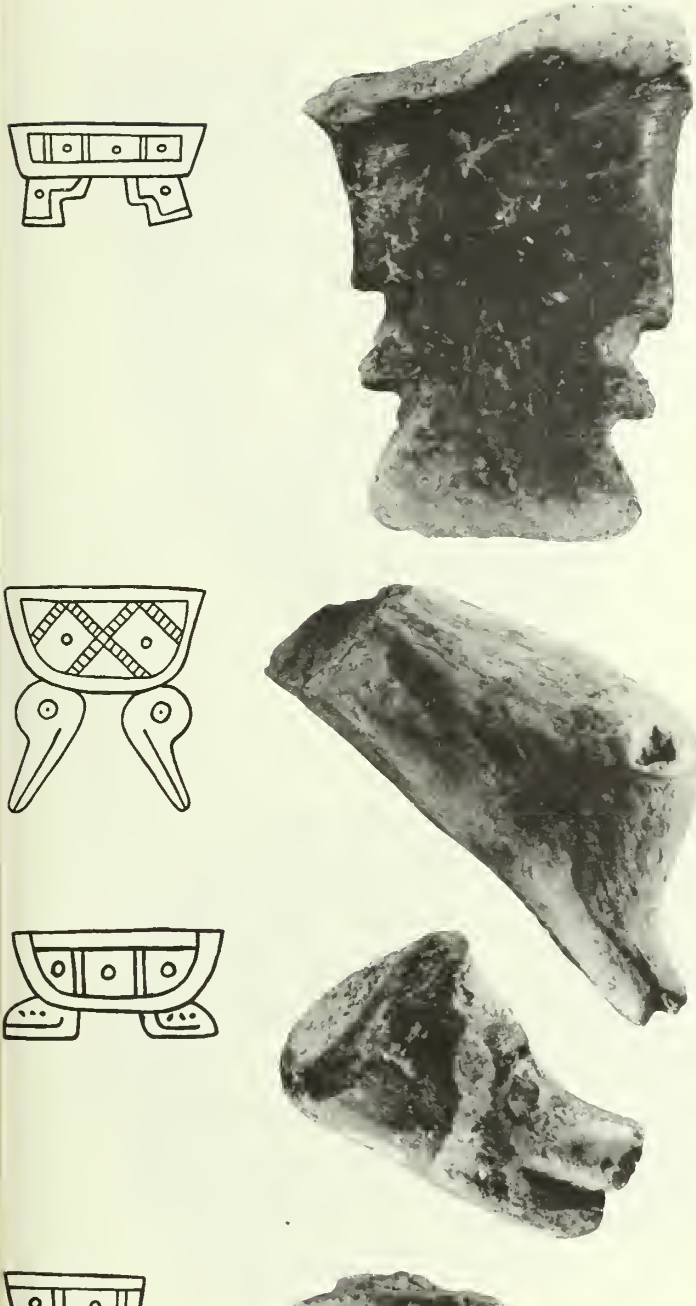

Fig. 73. Vessel supports from Venta Salada pottery and from Codex Borgia, pls. 57, 69, 1, 2.

tery and depictions of it in the Borgia usually have a white surface finish which is sometimes decorated with red bands. Archaeological specimens of similar vessels have been reported only from Cholula and the Venta Salada region.

Another distinctive pottery type, Coxcatlan Black on Orange (yellow in the codex), appears as flat-bottomed, out-flaring bowls, occasionally with loop handles, and is characterized by black stepped designs, usually filled with crosshatching. A classic example of this type is shown in the middle panel, right side, of Borgia plate 57.

Less striking resemblances are seen in three other wares. One of these is Coxcatlan Gray. A bowl of this type, with decorated stepped feet, may be shown in plate 57. Archaeological examples, such as the one shown in Fig. 75, usually have a design stamped on the bottom of the interior. The second type is Coxcatlan Polychrome. Archaeological specimens of this type have creamy white backgrounds decorated with orange or brown designs overlaid with fine red linear motifs. The type seems to be shown, albeit with somewhat different colors, on Borgia plate 61, upper center. The third ware is a vaselike vessel which has a red stepped design on a cream background (pl. 44) as does our type Coxcatlan Red-on-Cream.

The appearance in Codex Borgia of two vessel forms characteristic of Venta Salada pottery may also be significant. In Borgia plates 1–8, 26, and 47, for example, the pedestal-base form characteristic of Venta Salada pottery is seen. The second distinctive form is the *xantil*, an anthropomorphic, polychrome vessel, usually with a disproportionately large head on a small body. The mouth is usually open, so that when the hollow figure is set over an incense burner, smoke issues from it. Paddock (1966: 229) illustrates several of these vessels from the vicinity of Teotitlan del Camino, and Noguera (1940: pl. 6) illustrates a xantil he found near Calipan. Xantiles are known from Cholula, Veracruz, and other regions, but because of their frequency of occurrence in the Tehuacan Valley, we consider them to be a diagnostic trait of the Venta Salada phase. At the bottom of plate 38 of the Borgia a vessel which may be a xantil is depicted in the form of the rain god Tlaloc. This rendering has points in common with the Tlaloc *brasero* from the Tehuacan Valley described and illustrated by Bernal (1965*b*). A xantil that Seler acquired in Teotitlan del Camino and the face of the god Xochipilli in Codex Borgia displayed so many similarities that Seler was led to believe that the codex was painted in the vicinity of Teotitlan (1963: I, 101–103).

Perhaps the only completely new item that the

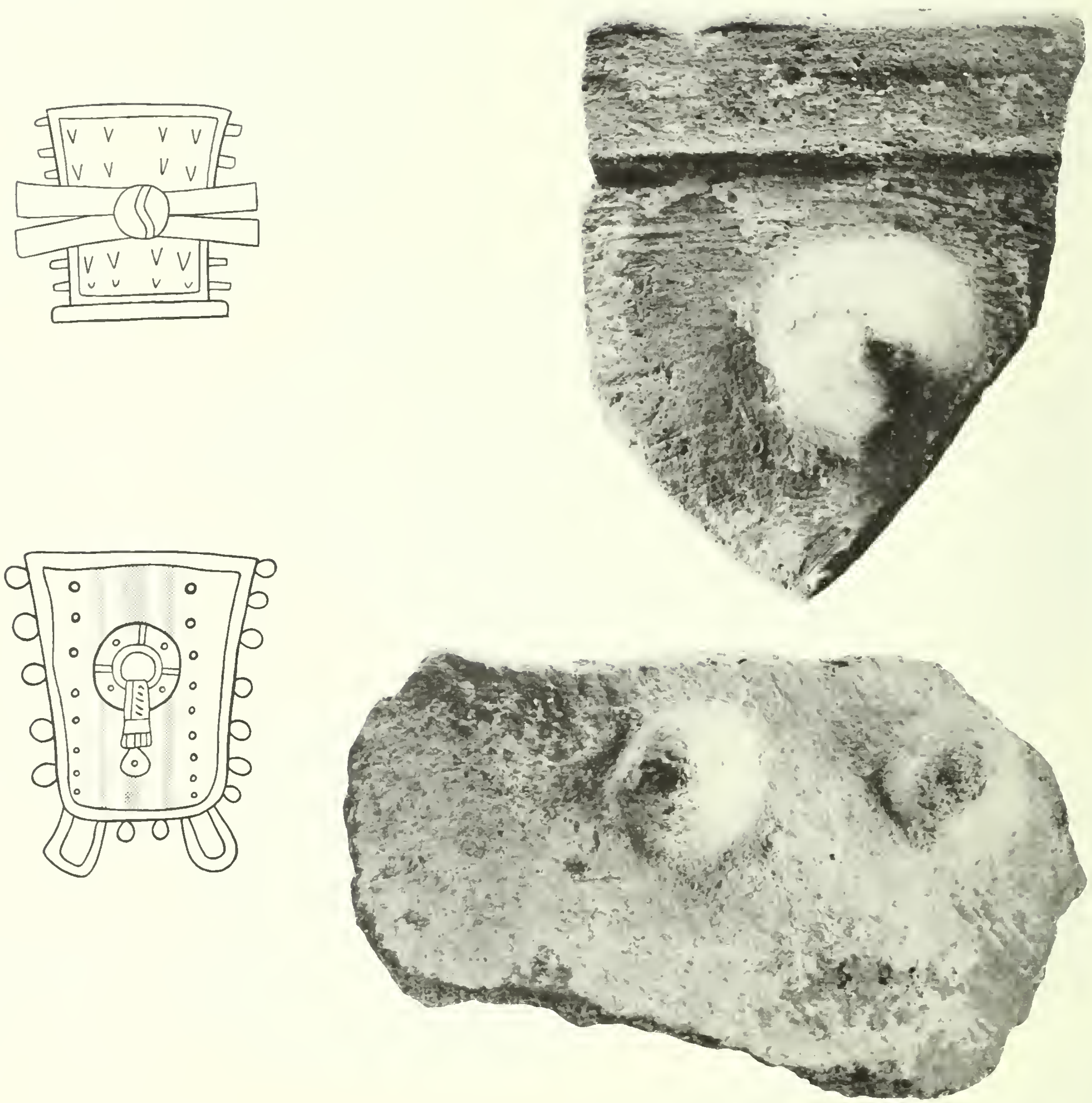

Fig. 74. Sherds of Coxcatlan Coarse with conical nodes and vessels with similar decoration from Codex Borgia, pls. 18 and 63.

Borgia can add to the Venta Salada ceramic complex is the clay pipe. On plate 58, middle row, right panel, the goddess Xochiquetzal holds in her right hand what appears to be a smoking elbow pipe with a vasiform bowl.

The Borgia Codex depicts many features of ceramics common to it and the ceramic complex of the Venta Salada phase. If we were to apply to the Borgia pots the same methods and techniques we use to classify the thousands of archaeological specimens, we would emerge with attribute clusters forming the following Venta Salada pottery types: Teotitlan Incised, Coxcatlan Red, Coxcatlan Coarse, Coxcatlan Black-on-Orange, Coxcatlan Gray, Coxcatlan Red-on-Cream,

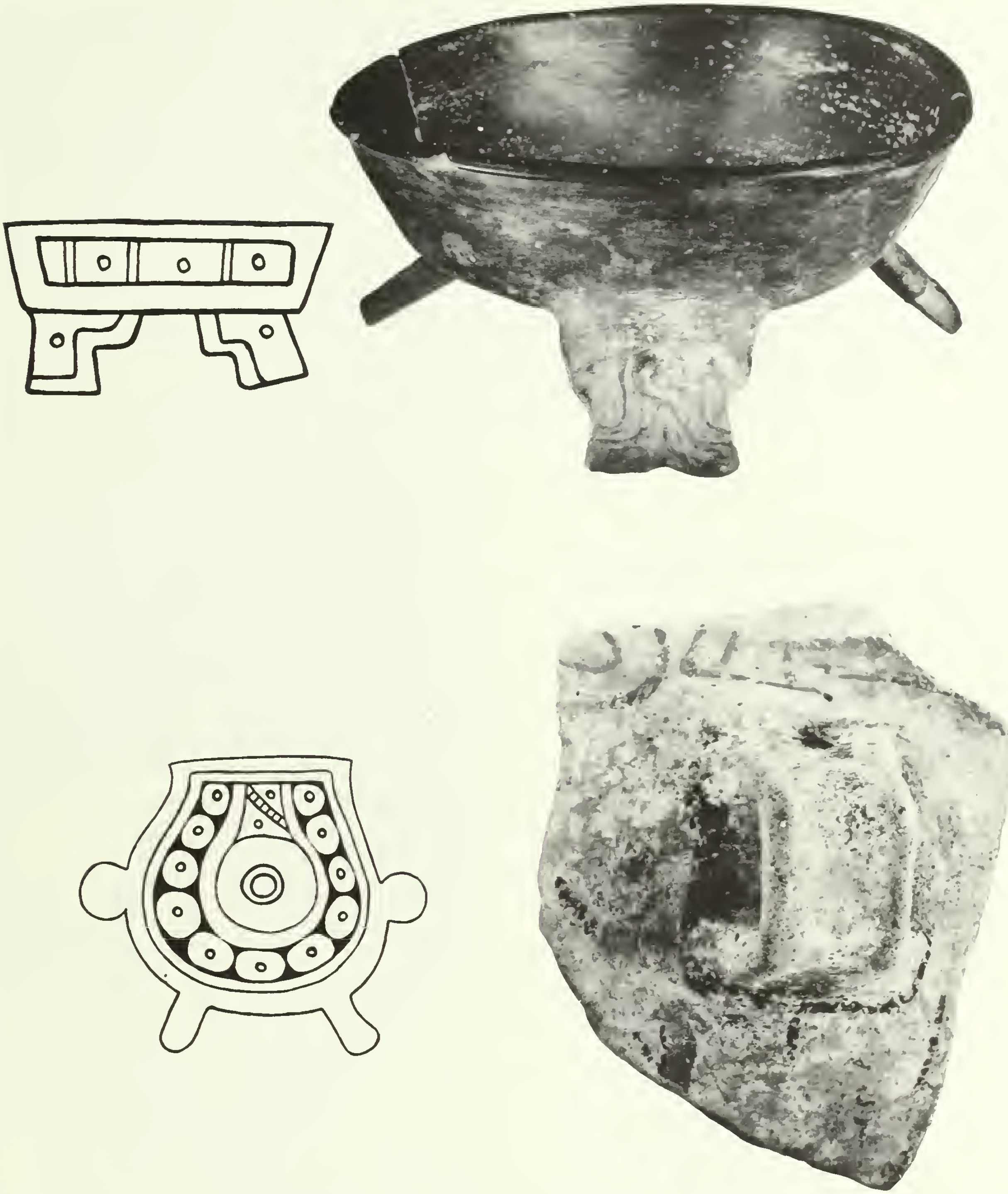

Fig. 75. *Above:* Bowl of Coxcatlan Gray (shown half-size) and a bowl of similar form from Codex Borgia, pl. 57. *Below:* Sherd of Coxcatlan Polychrome and a vessel from Codex Borgia, pl. 61.

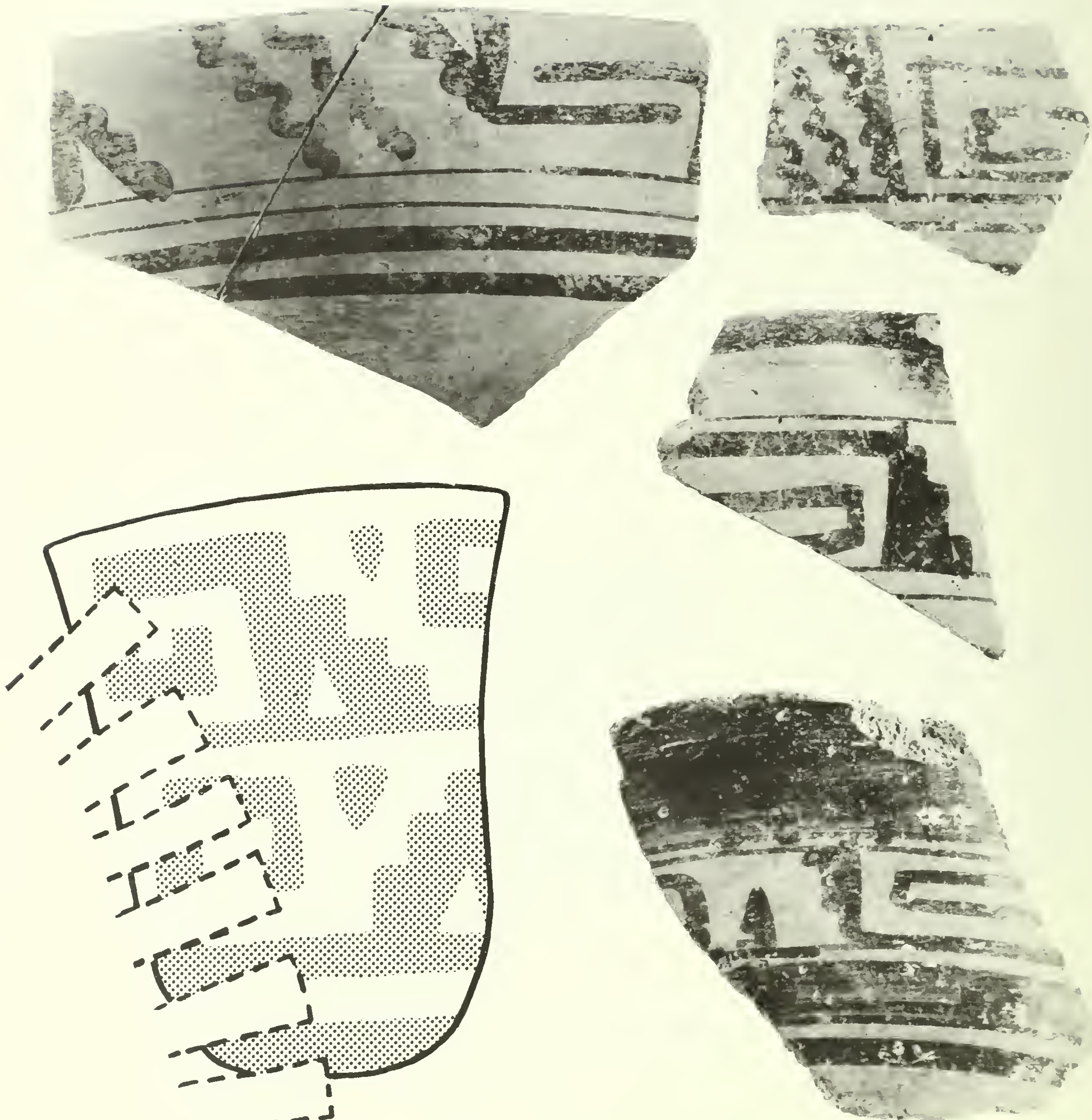

Fig. 76. Sherds of Coxcatlan Red-on-Cream and a vessel from Codex Borgia, pl. 44, with similar designs and colors.

Fig. 77. Tlaloc brasero from the Tehuacan region (courtesy Instituto Nacional de Antropología e Historia).

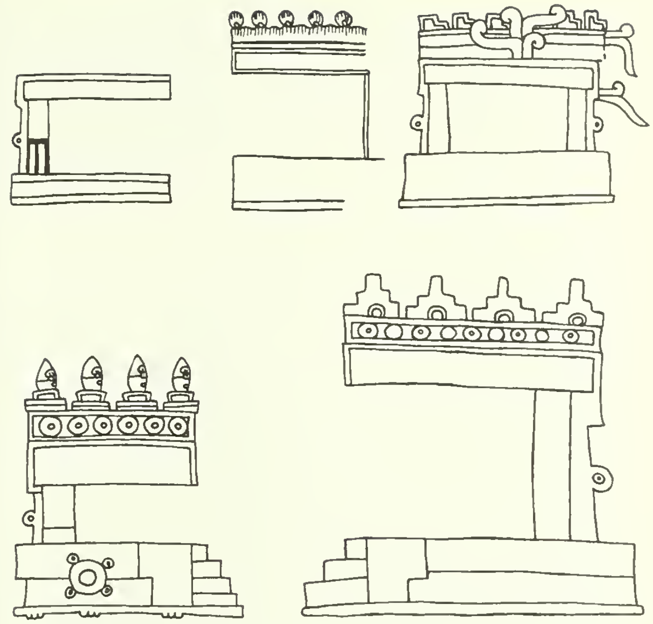

Fig. 79. Buildings with flat parapet, parapet with round or stepped merlons, and with rings shown projecting from sides and from back. Codex Borgia, pls. 45, 13, 50, 68.

Fig. 78. This building, possibly a chapel, at Tehuixtla, Puebla, illustrates the surviving use of stone platforms.

Coxcatlan Polychrome, and Tehuacan Xantiles. Thus, if we considered each depiction of pottery in Codex Borgia a ceramic vessel, we would have little hesitation in considering the codex a component of the Venta Salada phase. On the basis of Coxcatlan Polychrome, Coxcatlan Red-on-Cream, Coxcatlan Coarse, Coxcatlan Black-on-Orange, and Tehuacan Xantiles, one might seriate the ceramic collection and thus place the Borgia in the latter half of the Venta Salada period. The dominance of Teotitlan Incised and the three other types would tend to place it early in the last half of the period, say A.D. 1100 to 1300.

Let us now consider representatives of buildings and structures shown in Codex Borgia. House or temple platforms are of two main types, either simple truncated pyramids with from one to five steps leading to the summit (pls. 10, 12–14) or pyramids constructed in three to six steps, each with its panel and battered base (pls. 35, 37, 42). Many are shown with red and white bands or panels hinting that they were plaster covered and then painted. The use of the platform as a base for a building persists to this day.

Five kinds of buildings are shown on such platforms, most of them in cross section. Floors are formed by the top of the pyramid. Walls, and what appear to be slabs on which the roofs rest, are shown as narrow rectangles. The floor and slab extend a short way beyond the

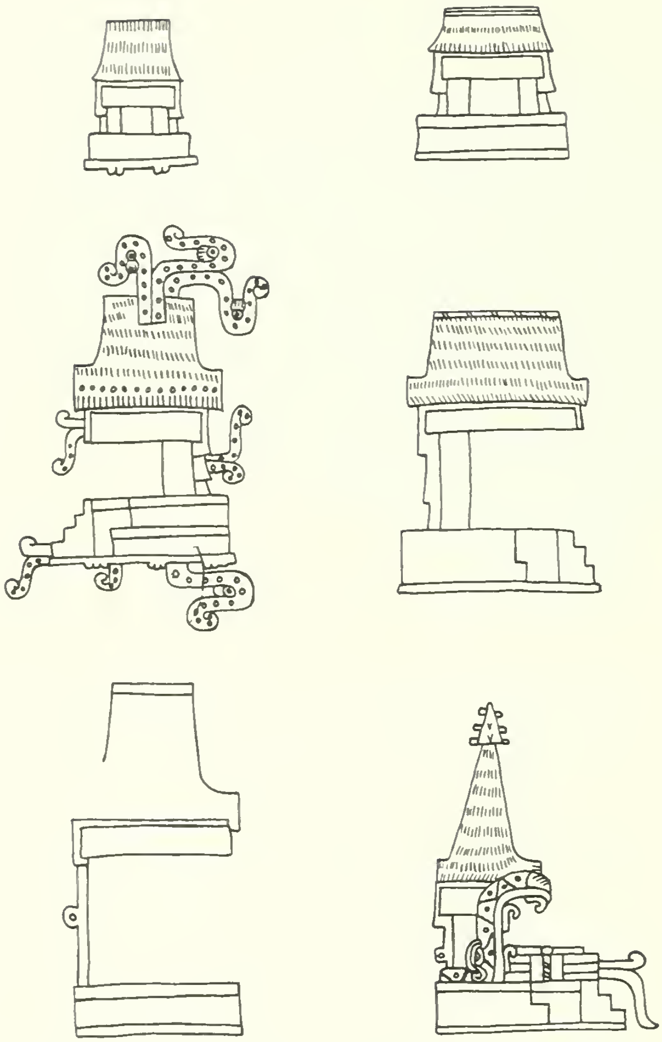

Fig. 80. Buildings and rooms. Codex Borgia, pls. 62, 66, 61, 55, 46, 14.

wall. Those buildings shown in section through the entrance doorway and back wall have no front wall, and the structure assumes the form of an inverted "L" turned in either direction. In this view the slab at the top may, in reality, have been a lintel. The artist may have been unable to conceive of a span without the support of a lintel.

Many houses have a curious ringlike or looplike projection fixed to an outside wall. Most frequently the loop is shown as though projecting from the back wall (pls. 1, 10, 12, 14, 37, 47, 49–51, 64, 68). Only twice is it shown as projecting from either side of a temple shown in front elevation (pls. 13 and 49), and not at all on the remaining houses, whether in front elevation (pls. 62, 63, 65, 66) or in side elevation (pls. 25, 26, 33–35, 55, 61, 74).

The last type of house is the same shape as those discussed above. The back wall, however, is not merely a rectangular block but a series of two or three separate courses, each wider than the one below it (pls. 5–8, 12, 18, 55, 61). The painting again suggests that these structures were plastered and then painted. Most commonly they are painted in red and outlined in white, although a few are all red, some are black with gray borders, some display red disks against a black background, and one has yellow and blue disks on a red background.

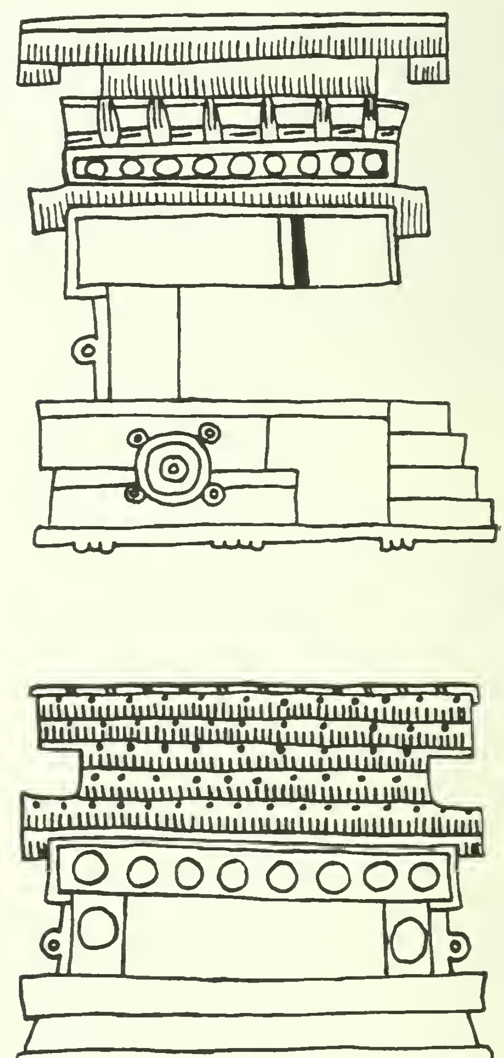

Fig. 81. Buildings with "eared" roofs. Codex Borgia, pls. 51, 49.

Fig. 82. An "eared" or Chocho-Popoloca roof in Acatepec, Puebla.

Roofs in a variety of forms cover these buildings, which may be temples or houses. All seem to be set on temple platforms. Roofs are either peaked or flat. The latter are less common and seem to be of two general types: those with flat parapets (pl. 45), and those whose parapets are topped with "battlements." Those with "battlements" include three subtypes, consisting of those with rounded merlons or almenas (pl. 45), with stepped merlons (pl. 13), or stepped pyramidal merlons (pls. 50, 51, 68). Some of these flat-topped roofs seem to have been painted and probably were plastered.

Thatch, the most common roofing material, may be applied over a frame made in different styles. Most common are simple roofs looking like the cross section of a truncated triangle; these have an external false ridgepole depicted at the summit (pls. 45–47, 55, 66). A few of the same form lack the external ridgepole (pls. 18, 62, 64, 65). Almost as common are gabled roofs which fall away to lower flattened eaves that may represent porches. This type of roof is shown without an external ridgepole (pls. 3, 4, 12, 61) as often as with one (pls. 2, 8, 46, 55). The least common type of roof shown in the codex (pls. 14, 40) appears to have been a conical structure, also with projecting eaves.

Another, and very distinctive, type is the Chocho-Popoloca roof. These are gabled roofs, the upper portion of which overhangs the gable-filling thatch at each end and rather resembles an ear. The gable of this projecting upper part of the roof appears to be closed by vertical flaps (pls. 34, 37, 40, 49, 51). Plate 49, lower left, lacks the vertical flap at the end of the gable but is otherwise similar.

A connection between Codex Borgia and the vicinity of the Tehuacan Valley seems to exist in these depictions of "eared" thatched roofs. According to Cook de Leonard, this type of roof is one of the outstanding characteristics of the Chocho-Popoloca-speaking people to the west of the valley (1953: fig. 58). It is apparently not found among the Mixtecs in Oaxaca, or the

Fig. 83. Village of Tehuixtla, Puebla, showing "eared" roofs.

Chochos in the Temazulipan-Tejupan-Coixtlahuaca area (Cook de Leonard 1953; Paddock, personal communication, 1965). Its depiction in the Borgia may help to eliminate Tlaxcala, the Cholula region, and most of the Mixteca Alta as well, from consideration as places in which the codex may have originated. Roofs similar in style to those of the Chocho-Popoloca are shown in a Mixtec pictorial, the Codex Sanchez Solis, whose exact provenience is unknown, but this does not necessarily render our thesis untenable. Although the codices Bodley, Selden, Nuttall, and Vienna show roofs similar in form to many in the Borgia, the distinctive eared roof of the Chocho-Popoloca area does not appear in any of them.

Codex Borgia contains more elaborate references to the Venus cycle—a count of which Aztec documents make only scant mention (Robertson 1963: 162)—than other ritual codices of its group. There is documentary evidence of the importance of the Venus cult in Teotitlan del Camino (Román y Zamora 1897: I, 170). According to Krickeberg (1956: 262–63), the Tehuacan Valley seems to have been the only locality in Mesoamerica outside of the Maya region where calculations of the cycle of the planet Venus were commonly made. This seems a further indication of the close connection of the Borgia with the Tehuacan Valley, for the Borgia is one of three manuscripts which contain a correction of the Venus cycle (Beyer 1965: 291-93). The other two are the probable Cuicatec codex, the Porfirio Díaz, and the Mixtec genealogical codex, the Nuttall (*ibid.*, 291).

We have noted similarities between ceramic forms pictured in the Borgia and actual archaeological specimens, and between roofs shown in the Borgia and modern roof types of the Tehuacan Valley and the region immediately to the west. There also are similarities between other forms of artifacts shown in Codex Borgia and archaeological types known from the Venta Salada phase. Unfortunately the material culture of the surrounding area is so poorly known that it is difficult to assess the value of these artifacts as evidence of a solely Venta Salada material culture.

We have discussed the evidence to connect the Borgia Codex specifically with the Tehuacan Valley. We believe the relationships summarized below indicate that the codex was painted in the Tehuacan Valley, by people with the material culture of the Venta Salada phase: (1) Two distinctive Borgia glyphs—that for Flint and an unusual version of the A–O year symbol—occur on Venta Salada artifacts. (2) Pottery types native to the Tehuacan Valley and diagnostic of the Venta Salada phase are depicted in the codex. (3) Houses with unusual eared gabled roofs, like those on Popoloca houses to the west of the Tehuacan Valley, are shown in the Borgia. (4) The cult of the planet Venus and its attendant ceremonies treated in Codex Borgia were practiced in the Tehuacan Valley.

Let us take the information contained in the Borgia Codex, as well as other evidence concerning the Tehuacan region, and attempt to supplement the cultural data derived from the archaeology of the Venta Salada phase.

Documentary sources add little to the information regarding the local subsistence pattern that we have derived archaeologically (see Chapter 15 below). In terms of sustenance, the documents mention corn, beans, and squash, but none of the other domesticated plants of which we found archaeological evidence, such as peanuts, guava, sapote, and avocado. Except for maguey and *Opuntia,* even less information exists about wild food stuffs. Although there are depictions of a number of animals in the Borgia, it contains no specific information about meat as food. Data concerning food preparation is equally slim in the documents. The Borgia paintings do show the old goddess of the sky grinding corn with a cylindrical mano on a tripod metate (pl. 9) very similar to our archaeological examples and goddesses of water and maize making nixtamal (pl. 43, lower left and right.)

Other pictures show pots containing fermenting pulque (pl. 2) or vessels in which things, mainly deities or their human representations, are being boiled (pl. 7).

People making fire by friction, with wooden implements like those we found, appear in plates 49–51. As

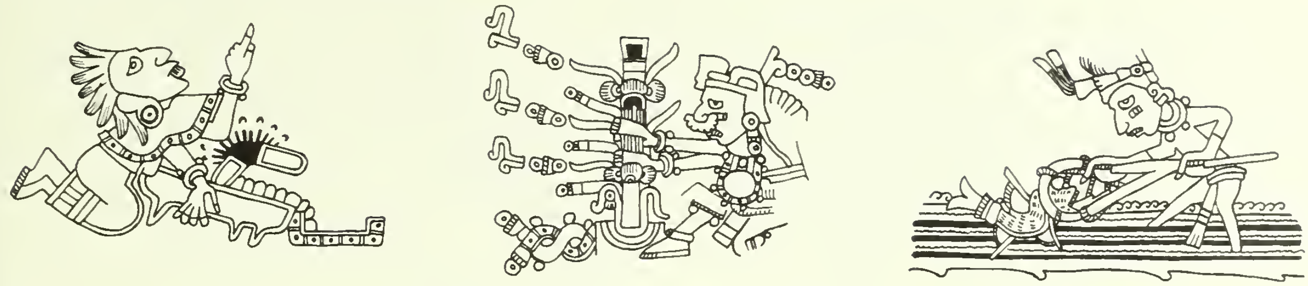

Fig. 84. Grinding corn, making fire, and netting fish. Codex Borgia, pls. 9, 51, 13.

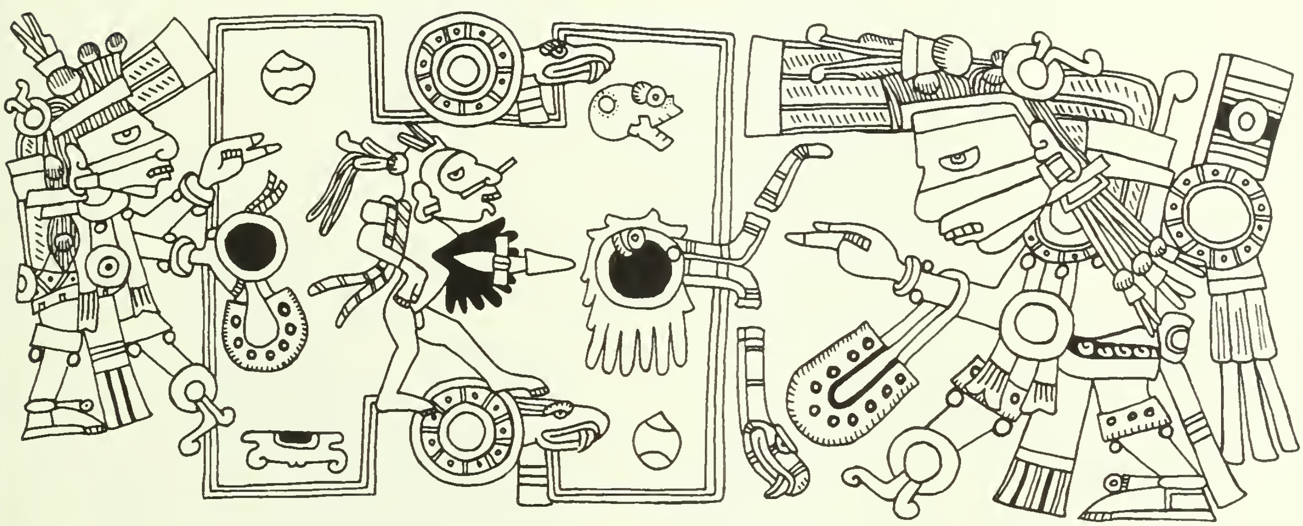

Fig. 85. Ball court with decorated stone rings, sacrificial victim and the god Tezcatlipoca. Codex Borgia, pl. 21.

will later be shown, all this data and much more can be derived from analysis of the archaeological collections.

Subsistence activities are not extensively recorded in the ritual manuscripts. The Borgia does include drawings that show speared deer (pls. 22, 52), wild animals probably marked for sacrifice by the pennants they bear (pls. 13, 20, 21; Seler 1963: I, 219), and jaguars stuck with flint knives (pls. 10, 24), but these tell little of hunting practices. The picture of a man catching fish with a dip-net shaped like a lacrosse stick (pl. 13) is revealing and closely parallels a similar scene in Codex Vaticanus 3773, plate 32.

In the Borgia there are drawings of ball courts in the shape of a flattened "H." Rings shown for the ball courts appear to be of stone (pls. 21, 35, 40, 42) and resemble remains of rings found on late sites in the Tehuacan Valley. They contrast significantly with ringless courts in Oaxaca and the Mixteca. Except for Codex Nuttall (pl. 74), Mixtec genealogical codices show ball courts without rings (Bernal 1965*a*: 807). This is further evidence of a tie between the Borgia and the Venta Salada phase.

The Borgia's rather stylized pictures of flint knives, blades, flint spikes, and large atlatl points tell us no more about the flint-knapping industry than we have learned from a study of the archaeological materials. Nowhere in the Borgia is there a picture of the bow and arrow, in spite of the fact that we found many small points which, in an archaeological collection, are normally classified as arrow points, and in spite of the fact that Motolinia (1903) speaks of the people of the Tehuacan Valley as great archers.

The only form of bone implement in the codex is a dagger (possibly made from a femur) that is sometimes shown being poked into the eye of a sacrificial victim (pls. 10, 16), held symbolically with an agave spine (pls. 22, 48, 59), or in other circumstances (pl. 22). Archaeologists usually call this tool a long bone awl.

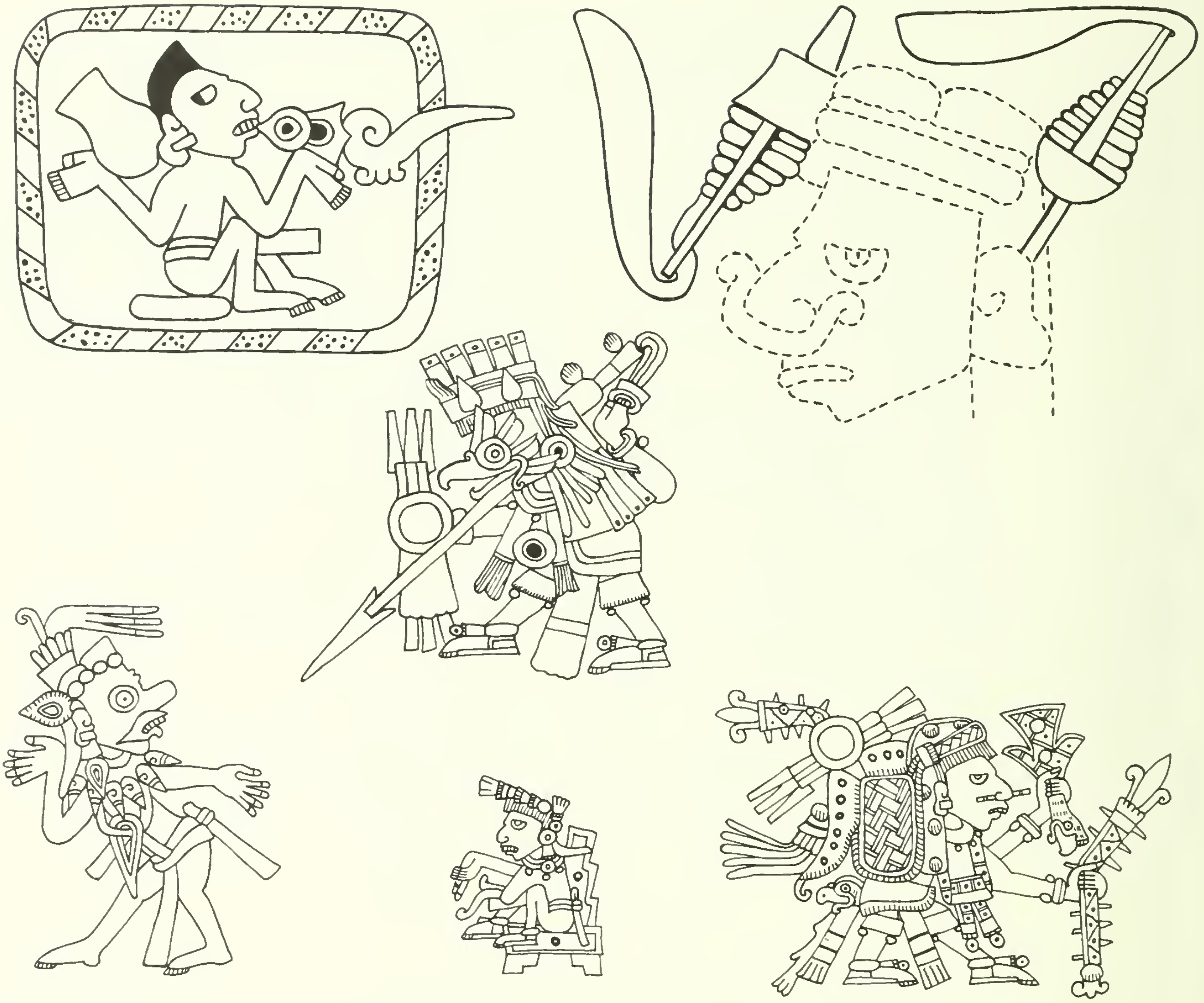

Fig. 86. Industries and artifacts: conch shell horn, clay spindle whorls, wooden atlatl and dart shafts, necklace of shell tinklers, wooden throne, and a merchant with woven headband, tump line of Z-twist cord, and twilled container for his goods. Codex Borgia, pls. 9, 64, 16, 54, 6, 55. Notice differences in male dress.

Few representatives of ground-stone tools are to be found in the codex or in early documents. Only square-based celts (pls. 1, 3–5, 12, 59), manos and metates (pls. 9, 43), and possibly stone bowls (pl. 9) are shown. These resemble Venta Salada tools.

Shell-working is represented by conch-shell horns (pls. 9, 24), triangular shell gorgets (pls. 55, 57), gear-like multipointed round gorgets (pls. 22, 25), and oliva-shell gorgets. Although we found none of the foregoing types in the excavations, we did find pierced oliva shells that could have served as tinkler bracelets (pl. 55) as well as necklaces (pls. 55, 56, 64); earrings (pl. 64); disk and spherical shell beads; and fragments of what possibly were round shell gorgets. All of these, also, are shown in the Borgia.

Graphic evidence from Codex Borgia supplements knowledge derived from the archaeological collection of perishable artifacts. Here one really derives more information from documentary sources than from excavated materials.

An extensive wood-working industry is shown in the Borgia. Paintings of atlatls (for example, see pl. 25) and atlatl darts or lance shafts probably made of wood occur throughout the manuscript. Equally common are long triangular wooden handles for knives or daggers and wooden handles for celts or axes (for example, pl.

Fig. 87. Ornately dressed women. Codex Borgia, pls. 59, 16, 9.

19). The handles are usually painted yellow or brown, apparently to indicate that they were of wood. Other wooden implements include clubs shaped like cricket bats with inserted obsidian blades; a cleaver-like "hoe" with which the god Tlaloc is cultivating a cornfield (pl. 20; cf. Volume II of this series, fig. 138); small round "shields" (pl. 17) which are shown in the hands of individuals; "batons" in the hands of priests (pl. 1); long canelike staffs that are carried by merchants (pls. 4, 21); and "palos de sonajas" (rattle staffs), a staff sometimes striped and with a pointed end, which possibly was used for music (pls. 49, 56, 73). Certainly the fire drills and the hearth shown in the lower panels of plates 49, 50, 51, and 52 were of wood. On plate 18, the sun god, Tonatiuh, seems to be holding a wooden spoon or ladle, and on plate 3, the goddess of fire appears to be carrying a gourd rattle. On plate 70 there may also be a depiction of a digging stick, in this instance being used to push someone down into a tank of water. Wood must have been used in the construction of some architectural features, such as roofs and most lintels, and probably for all the furniture, for example, the throne in plate 6.

One class of object called "banderolas" in the Spanish translation of Seler (1963) occurs throughout the Borgia; undoubtedly it had a wooden handle. Seler believed that the flag portion was of bark cloth. He also believed that the paper ornament worn by sacrificial victims was of the same material (1963: I, 111, right). Bark cloth and bark beaters appear among archaeological remains of the Venta Salada phase. Closer study of the Borgia would undoubtedly disclose other tools of wood, but even this superficial survey gives conclusive evidence of a wood-working industry.

Among the perishable artifacts depicted in the Borgia, textiles are perhaps the most frequently shown. The merchants in plate 55 are carrying their wares in twilled baskets and are using tump lines for the purpose. On plate 19 there is a painting of what appears to be a petate. Two-ply cord, probably of coarse-fibered yarn, is shown as both Z-twisted (pl. 3, section 15, bottom; pl. 6, section 39) and S-twisted (pl. 3, section 15, top). Spindle whorls are shown in two general forms, truncated cones (pl. 16) and disk-shaped or plano-convex disks (pl. 12). All these items appear among the artifacts of the Venta Salada phase.

Male clothing, generally speaking, is less ornate than female attire. The predominant article of male clothing is the loin cloth. This garment, probably nothing more than a length of cloth made on a back-strap loom, was worn between the legs and wrapped around the waist. The front end passes over the wrap and hangs below the knees, while the back end is usually tied, perhaps with a reef knot, its free end often hanging to the ankles. Some ornately dressed males wear decorative cloths about the hips and fringed capes, perhaps poncho-like garments, that hang from the neck to the waist (pl. 9). A few other men wear what seems to be a cape over the shoulders.

Women's clothing shows more decoration, and the width of some skirts and capes suggests that these objects were made either by sewing together strips woven on a back-strap loom, or perhaps by using cloth made on a wide loom. Women usually wear very decorative skirts that extend to or slightly below the knees. Equally ornate are shoulder capes and ponchos. Rectangular ponchos (*quechquemitl*) hang from the neck to the waist with pointed corners showing. Other ponchos show a rounded sinuous edge.

Exotically dressed personages of both sexes often wear woven sandals. Like those of archaeological examples, the woven sole is usually short, so short that the toes are shown extending fully beyond it. The

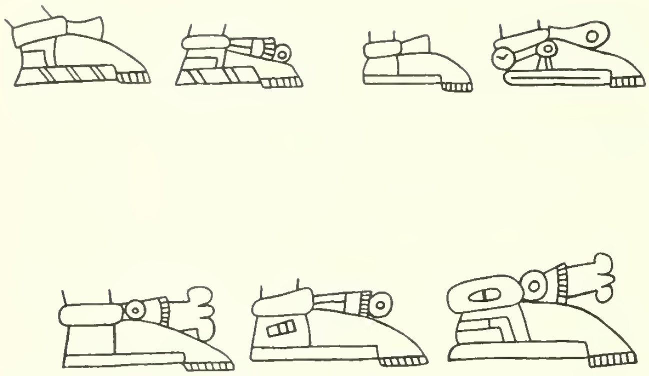

Fig. 88. Sandals with different types of ties and heel supports shown in Codex Borgia.

sandals also have what seems to be a woven rectangular heel cup that extends up to the ankle strap. Methods of tying straps vary. Some are tied with a single sash at the front, some with a double sash or a looped sash with a strap around the loop. The sandals with a small round tab over the instep shown throughout the Borgia differ from those shown in other codices of the group. Excavated specimens appear to duplicate the Borgia types, especially the sandals with the small tab or loop over the instep (Fig. 88).

Even some of the headdresses, such as the one Quetzalcoatl wears on plate 9, include some woven parts. Generally speaking, however, the headdresses are so complex and so varied that they cannot be described in this context. If they represent the handiwork of any industry other than that of mask-makers, milliners, or hatters, it is probably that of feather-workers and jewelers.

The jewelry- or ornament-making industry is represented by more than parts of headdresses. Over fifteen varieties of ear ornaments are shown, ranging from simple disk plugs to ones with a large variety of dangling objects, including even a human hand (pl. 13). Almost as many types of nose plugs, and even what may be a lip plug, are depicted. Many figures wear necklaces, and although these seem to be of only five or six basic kinds, about a dozen types of gorgets or pendants may be attached to them. Five types of bracelets, some with appendages, and twelve kinds of leg bands or garters worn just below the knee appear in the drawings.

Codices give evidence of other technological activities, many of which were in the hands of artisans whose specialty was one product. Obviously not the least of these were the artists who painted not only Codex Borgia, but also other codices, murals, figurines, and so on. Highly evolved styles, skills, and conventions testify to a schooling and discipline developed over many generations by a closely knit guild of expert craftsmen. Their consummate skill has made it possible for us to recognize in their work the artifacts which we have known only from excavated fragments. Further study of the Borgia may increase our knowledge of the religious and ceremonial life of the people who are responsible for the Venta Salada material remains.

Although we cannot with certainty place Codex Borgia in the Tehuacan Valley, we have been able to point out certain striking resemblances between drawings in the codex, on the one hand, and archaeological traits and a modern distinctive form of roof, on the other. Detailed excavation of the numerous Classic and Postclassic sites within the boundaries of the Tehuacan Valley was beyond the purposes and scope of the Tehuacan Archaeological-Botanical Project, which was designed to seek out the beginnings of agriculture and civilization through establishment of a complete archaeological sequence as explained in Chapter 1. Certainly the close parallels between Codex Borgia and the Venta Salada phase of that sequence point to the need for further investigations in both the valley and the adjoining area to the west. A more complete record of painted representations almost certainly exists in some of the large Venta Salada sites in the valley, and we confidently expect that they will confirm our hypothesis.

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CHAPTER 8

Vertebrate Fauna and Hunting Patterns

Kent V. Flannery

In 1962 and 1963 I conducted zoological investigations of two types in the Tehuacan Valley. One involved analysis of animal bones from archaeological sites, spanning the period from perhaps 9000 or 10,000 B.C. to A.D. 1500. The other consisted of the accumulation of skeletons of present-day fauna from the region as a comparative study group by means of which the prehistoric bones could be identified. In conjunction with the latter study, notes were made on the modern fauna, and the stomach contents of animals collected were analyzed by Eric O. Callen of Macdonald College of McGill University, whose notes are published at the end of this chapter. Since the zoological research was primarily concerned with the animals eaten by the prehistoric inhabitants of the Tehuacan Valley, our information is incomplete for most of the smaller or less commonly eaten vertebrates; for other animals we have reliably dated evidence going back some ten thousand years.

Within the larger environmental unit of the Tehuacan Valley, local differences in rainfall, drainage, exposure, and the nature of the bedrock have combined to produce four main local environments or subareas and a few specialized niches. These subareas, with their various geological features and differing plant and animal communities, were originally outlined by James Schoenwetter and are generally recognized by the several scholars contributing to this volume, although we do not refer to them in identical terms. The four subareas and the specialized niches within them, as reflected by the faunal remains and my own observations in 1962–63, are described below.

1. The Valley Center and Broad Travertine Terraces on the West Side

Subarea 1, whose fertile, deep alluvial soil is the best agricultural land in the valley, has been intensively cultivated for the last two thousand years, making it difficult to determine the "original" flora. Similar stretches in the valley of the Rio Calapilla and some uncultivated patches in the Tehuacan area itself, however, suggest that this was probably mesquite-grassland, at least in areas of higher water table such as the Ajalpan plain. Besides mesquite (*Prosopis juliflora*), other wild tree legumes grow in the region, as well as small shrubs like "coyotomate" (*Castela tortuosa*) which bear fruit in the rainy season (June-September).

Our best look at the more common edible fauna of the area actually comes from village remains from the first and second millennia B.C. (Ajalpan and Santa Maria phases), before intensive irrigated cultivation began. The following lists give the most frequent animals in the area.

MAMMALS

- *Sylvilagus audubonii*
- *S. cunicularius*
- *Heterogeomys* sp.
- *Dipodomys phillipsii*
- *Liomys irroratus*
- *Reithrodontomys fulvescens*
- *Peromyscus* spp.
- *Canis latrans*
- *Urocyon cinereoargenteus*
- *Mephitis macroura*

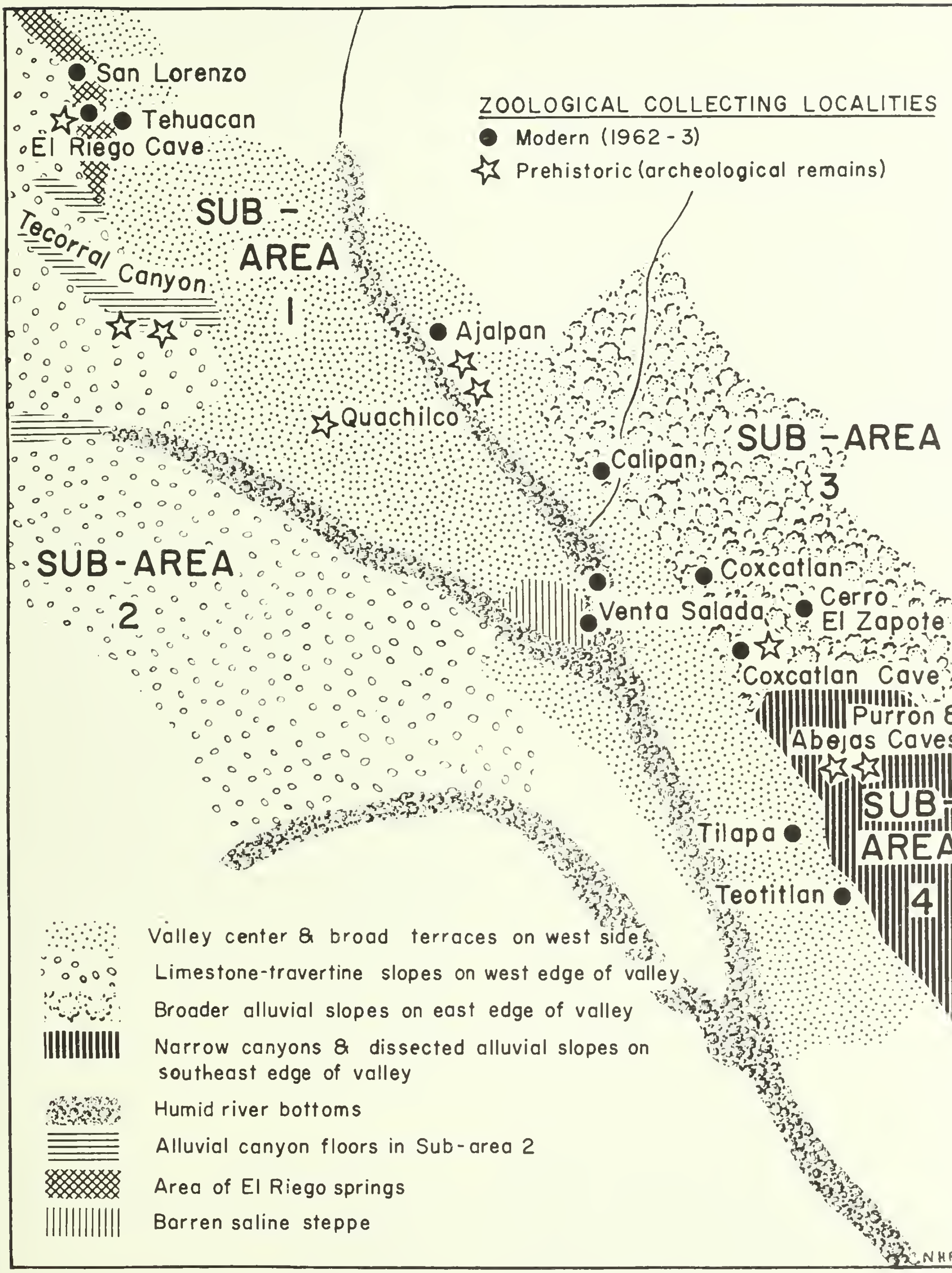

Fig. 89. Ecological subareas of the Tehuacan Valley.

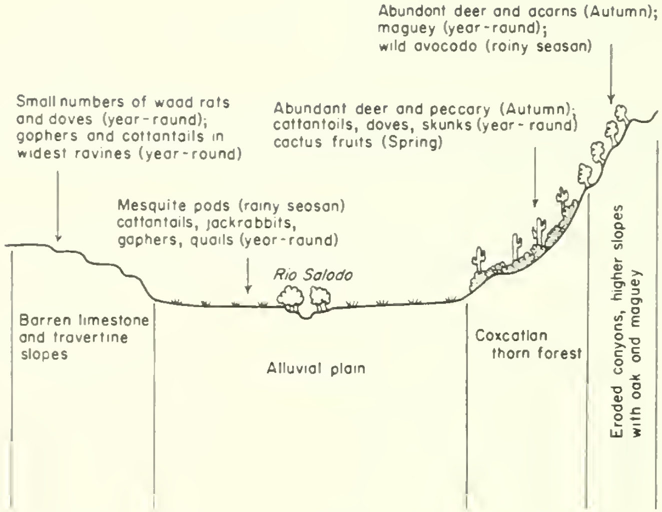

Fig. 90. Idealized cross section of the Tehuacan Valley, showing some of the environmental zones and the seasons in which the fauna exploited various resources. After Coe and Flannery 1964.

Lynx rufus
Odocoileus virginianus

BIRDS

Colinus virginianus
Zenaida asiatica
Columbigallina passerina
Corvus corax
Caprimulgus ridgwayi
Chordeiles acutipennis

REPTILES

Ameiva undulata
Phrynosoma spp.
Ctenosaura pectinata

Specialized Niche: The Arroyos of the Rios Salado, Zapotitlan, and Calapilla. This environmental milieu within Subarea 1 is defined as the gravel beds of the rivers mentioned above, the vegetation lining their banks, and the first few meters of their flood plains. By far the most humid niche within the valley system, this was probably a more extensive habitat in pre-Columbian times, before check-dams were built to hold back the water of the upper Rio Salado for irrigation. Today the river has water only in the lower half of the valley (below its confluence with the Barranca de los Mangos and the Rio Zapotitlan), but formerly its northward extent must have been much greater. Previously it also received water from the El Riego mineral springs, much of which is now commercially bottled.

All three of these rivers are shallow and mildly alkaline, trickling through only a small area of their wide gravel beds. At Venta Salada, west of Coxcatlan, the Rio Salado flows only thirty centimeters deep. This is sufficient, however, to produce a "river-arroyo" vegetation somewhat lusher than any other in the valley; parts of the area between the five-meter-high bluffs of the river bank are very densely thicketed. Many riverside areas are known as "quebrachales" (Miranda 1948:346), dominated by dense stands of the "quebracho" (*Acacia unijuga*) and the "chintoborrego" (*Vallesia glabra*), a tall fruit tree growing only in regions of high water table. Also present are thickets of a local river cane (*Phragmites communis*), as well as reeds and "palo de agua" which grow on sandy gravel bars in the river itself. There are numerous sloughs along the lower Rio Salado where marsh weeds are added to the plant community.

This river-arroyo habitat almost rivals the Coxcatlan region (Subarea 3) in terms of animal resources, for it supports not only large populations of many of the species found in other parts of the Tehuacan Valley, but also a unique fauna occurring nowhere else in the area. The only turtle known today from the Tehuacan Valley is a mud turtle *(Kinosternon integrum)* inhabiting the Rio Salado and its tributaries. The green iguana *(Iguana iguana)*, a tropical form which is an unexpected resident of the arid valley, appears to be restricted to the humid river-bank vegetation of this specialized habitat. The cinnamon teal (*Anas cyanoptera*) feeds in the sloughs on the lower Rio Salado from November through February, and killdeer (*Charadrius vociferus*) are also common along the river bank in the dry season. Besides these localized forms, extremely high populations of opossum and cottontail (especially *Sylvilagus cunicularius*) occur in the river arroyos, and archaeological remains from the area suggest that collared peccary may once have been plentiful there. Doves and quail are among the birds feeding in this habitat during the rainy season, when the chintoborrego bears fruit and thousands of weed seeds are ripe. Deer are still known from the floodplain of the Rio Calapilla, where a pair were sighted in July 1962.

The following forms are common in this specialized niche.

MAMMALS

Didelphis marsupialis
(and probably *Marmosa canescens*)
Sylvilagus audubonii
S. cunicularius
Liomys irroratus
Reithrodontomys fulvescens
Peromyscus spp.

Urocyon cinereoargenteus
Procyon lotor
Pecari tajacu
Odocoileus virginianus

BIRDS

Anas cyanoptera (winter)
Colinus virginianus
Charadrius vociferus (winter)
Zenaida asiatica
Casmerodius albus

Formerly:
Grus canadensis

REPTILES

Iguana iguana
Kinosternon integrum

Specialized Niche: The Short-grass Steppe West of Venta Salada. West of the confluence of the Rio Zapotitlan and Rio Salado, near the Venta Salada railroad stop, lies an area roughly two kilometers by one kilometer devoid of all but short-grass cover and an occasional tree legume. High salinity and extremely shallow soil may be contributing factors in forming this barren plain, for a major salt-producing site of the Postclassic period is located on the edge of the steppe, which occupies a flat limestone terrace three to five meters above the arroyo of the Rio Salado. The salt industry depended on seeps from saline springs in the cliffs to the west, which presumably have saturated the whole area. Here occurs one of the few populations of white-sided jack rabbit (*Lepus callotis*) we observed in the Tehuacan Valley, a region normally dominated by cottontails. Kangaroo rats are numerous on the open plain, nighthawks nest under the scarce leguminous trees, and hawks and owls scour the area for small rodents. This specialized niche within Subarea 1 is located close enough to the Rio Salado arroyo so that the fauna of the latter area (especially opossum and cottontail) can also venture into it nocturnally when the grass sprouts are young and the mesquite trees bear seed pods. The most common forms are the following.

MAMMALS

Lepus callotis
Dipodomys phillipsii
Liomys irroratus
Peromyscus spp.
Mephitis macroura

BIRDS

Caprimulgus ridgwayi
Chordeiles acutipennis
Buteo sp.

Fig. 91. Subarea 2. Level top of La Mesa, looking toward Sierra de Zongolica.

2. The Limestone-Travertine Slopes and Steppes on the West Edge of the Valley

In Subarea 2 the rainfall is particularly low, the ground is barren limestone or travertine with little or no soil, and the plant community includes forms which can extract water from porous rock. The tree cover, such as mesquite, vanishes and is replaced by barrel cactus, yucca, lechugilla, and "mala mujer" (*Jatropha urens*). Drainage is rapid (either through surface run-off or rapid penetration of the travertine) and ground cover sparse, making this faunally one of the poorest subareas in the valley. Rock squirrels live in the bare cliff faces overlooking the alluvial plains, and wood rats inhabit the steep limestone canyons leading back toward Zapotitlan.

White-winged doves feed on cactus fruit in the area, and hawks are common; there is little to attract quail or ground doves, however. Large race-runner lizards (*Ameiva undulata*) speed over the bare rock during the rainy season (May-November), but disappear in the winter, along with most of the insects on which they feed. The following incomplete lists give only the animals commonly sighted by us in this subarea, or recovered from local archaeological sites.

Fig. 92. El Riego Cave; sparse vegetation on the top and face of La Mesa contrasts with lush growth along its base.

MAMMALS

Lepus callotis
Sylvilagus audubonii
Citellus (Spermophilus) mexicanus
Peromyscus spp.
Neotoma spp.
Spilogale augustifrons

BIRDS

Zenaida asiatica
Buteo sp.

REPTILES

Ameiva undulata

Specialized Niche: The Floors of Tecorral Canyon and Related Deep Barrancas. This isolated niche, restricted to the floor of the wide canyons in the travertine cliffs west of the valley, is an area of well-developed alluvial soils with mesquite and other "wet area" plants combined with patches of grass. This plant community is cut off from the rest of the alluvial areas in Tehuacan by the barren travertine walls which surround it, through which few plants can successfully pass unless they have the ability to extract water from porous rock, as does much of the flora of Subarea 2. Radical differences exist between the canyon walls or rim and the floor, where water flows occasionally in the rainy season and may have flowed steadily in the Pleistocene. This specialized niche is described by Paul C. Mangelsdorf as an extremely probable habitat for wild corn; in fact, cobs of morphologically wild corn were excavated from San Marcos rock shelter in Tecorral Canyon (see below, Chapter 9). Included in the faunal remains from the same rock shelter and one adjoining it were the forms listed below, which are probably more common in Tecorral Canyon than in the rest of Subarea 2.

MAMMALS

Sylvilagus audubonii
S. cunicularius
Cratogeomys sp.
Dipodomys phillipsii
Liomys irroratus
Peromyscus spp.
Sigmodon hispidus
Urocyon cinereoargenteus

Fig. 93. Subarea 3. Thorn-scrub and cactus forest during the wet season. Fig. 135 shows dry-season aspect of same area. Photo C. E. Smith, Jr.

Mephitis macroura
Pecari tajacu

BIRDS

Colinus virginianus
Zenaida asiatica

Specialized Niche: The El Riego Springs and Adjoining Areas of the Valley Floor. The Cerro de la Mesa is porous travertine bearing for the most part the typical yucca and lechugilla vegetation of Subarea 2. The cliffs where it descends to the plain of Techuacan are barren white rock to which agaves, cacti, and an occasional scrawny tree cling, and soil is virtually nonexistent. At the base of the cliffs, however, tremendous quantities of subsurface water burst out through a series of large mineral springs which formerly drained into the Rio Salado. Today these springs support five bottling works —Tehuacan, Peñafiel, San Lorenzo, Garci-Crespo, and El Riego—with enough water left over for irrigation agriculture on the plain of Tehuacan. There is evidence that in the past the flow may have been even greater (see above, Chapter 5).

The soil on the Tehuacan plain is alluvial sediment, and it combines with the high water table along the El Riego cliffs to produce a belt of atypically lush vegetation. Mesquite, guaje, ciruela, and other trees alternate with occasional dense weed patches along the streams and irrigation canals, and the spring site of San Lorenzo supports the largest single tree in the valley, a "tule" or cypress which is clearly many centuries old. Large prickly pear and organ cactus flank the cliffs, and scattered patches of grass afford cover for cottontails, small rodents, and bobwhites. Raccoon and opossum tracks line the banks of the irrigation canals, and rock squirrels nest in the cliffs. Only a meter or so above the valley floor, where the alluvial soil vanishes, the unusual El Riego vegetation gives way to more typical Subarea 2 succulents and agaves, making this a region of interesting diversity.

Most common today, or in the bone remains from El Riego Cave, are the following animals.

MAMMALS

Didelphis marsupialis
Marmosa canescens
Lepus callotis
Sylvilagus audubonii
S. cunicularius
Heterogeomys sp.
Dipodomys phillipsii
Liomys irroratus
Reithrodontomys fulvescens
Peromyscus spp.
Baiomys musculus
Sigmodon hispidus
Urocyon cinereoargenteus
Procyon lotor
Mephitis macroura
Pecari tajacu
Odocoileus virginianus

From caves:

Eptesicus fuscus
Neotoma alleni
N. mexicana

BIRDS

Day:

Colinus virginianus
Zenaida asiatica
Columbigallina passerina

Night:

Caprimulgus ridgwayi
Chordeiles acutipennis
Tyto alba

In addition, a night trip to the El Riego cliffs afforded us our only glimpse, on July 27, 1962, of the unusual elf owl (*Micrathene whitneyi*) roosting high on an organ-pipe cactus.

3. The Broader Alluvial Slopes on the East Edge of the Valley

Subarea 3 consists of gravelly downwash and talus slopes where precipitation has formed a vast dendritic network of arroyos and some subsurface flows. A few arroyos, like the Barranca de los Mangos, near Calipan, have water even during the dry season. Here the vegetation of the valley, in Smith's words, "most nearly approaches a forest" (Smith, 1965*b*: 117), with a broad canopy closing one and one-half to two meters above the ground. The flora is thickest along arroyo edges and thins out in other areas, with patches of grass occurring in the gaps. Probably no part of the Tehuacan Valley offered prehistoric man more hunting and plant-collecting resources than this subarea, with its abundant cover for all kinds of animals and its high proportion of vegetal foods.

Tall tree legumes and the *pochote* tree (*Ceiba parvifolia*) make up part of the canopy. Present also are wild fruit trees like chupandilla, cosahuico, and ciruela; pod-bearing trees whose seeds are eaten (guaje blanco, guaje colorado, garabatillo); countless thorny shrubs; and several kinds of large cactus whose fruits are edible, including the prickly pear (*Opuntia* sp.), pitahaya (*Lemaireocereus* sp.), organo, and tetecho. The food supply changes seasonally, with cactus fruits appearing in April and lasting until July, tree legumes bearing pods in the rainy season (June to August), and wild fruits like chupandilla coming ripe in September. Even in the middle of the dry season (December-February) there are bushes like the tempixquistle (*Bumelia* sp). whose fruit can be eaten.

Animal populations in the area are correspondingly high; most of the coyotes and white-tailed deer remaining in the Tehuacan Valley are to be found in this subarea. Along wet barrancas, opossum, raccoon, and ring-tailed cat (*Bassariscus astutus*) occur, and striped, spotted, and hog-nosed skunks frequent the forested talus slopes. Owing to the abundant ground cover, cottontails of two species (*Sylvilagus cunicularius* and *S. audubonii*) are common. On a single evening (July 28, 1962) between 6:20 and 6:45, we saw five cottontails active along a narrow one-kilometer stretch of trail. The impossibility of telling young *S. cunicularius* from adult *S. audubonii* at a distance just at dusk prevents our giving relative proportions of these species, but archaeological remains from levels laid down during the modern climatic regime suggest that 70 percent of the cottontails in the Coxcatlan area are Audubon cottontails.

The most common mammals we observed at night in this subarea were, in order of frequency, kangaroo rats, deer mice, cottontails, striped skunks, and opossums. Birds normally seen in the evenings were nightjars, white-winged doves, and an occasional owl. By day, much of the game is hidden, but black iguanas (*Ctenosaura pectinata*) and white-winged doves (*Zenaida asiatica*) are still seen regularly. The archaeological evidence showed that cotton rats (*Sigmodon hispidus*), spotted skunks (*Spilogale augustifrons*), and gray foxes (*Urocyon cinereoargenteus*) had been numerous in the area for thousands of years, but we never personally observed them. The list of animals fairly common in this subarea, past and present, is extensive.

MAMMALS

Present throughout area, or of unknown habitat:

Marmosa canescens
Artibeus sp.
Eptesicus fuscus
Sylvilagus audubonii
S. cunicularius
Cratogeomys sp.
Dipodomys phillipsii
Liomys irroratus
Peromyscus spp. (esp. *melanophrys*)
Sigmodon hispidus
Canis latrans
Urocyon cinereoargenteus
Spilogale augustifrons
Mephitis macroura
Conepatus mesoleucus
Felis concolor
Lynx rufus
Pecari tajacu
Odocoileus virginianus

Present along watercourses:

Didelphis marsupialis
Bassariscus astutus
Procyon lotor

From caves:

Neotoma alleni

COMMON BIRDS

Day:

Colinus virginianus
Zenaida asiatica
Columbigallina passerina

Night:

Caprimulgus ridgwayi
Tyto alba

REPTILES

Ctenosaura pectinata
Ameiva undulata

4. Narrow Canyons and Dissected Alluvial Slopes on the Southeast Edge of the Valley

Subarea 4 might just as accurately have been considered a niche within Subarea 3, for it lies within and alternates with the latter. These canyons have a lower canopy (closing at about one meter) and no grassy patches such as occur in the Coxcatlan area. The best-known collection locus in Subarea 4 is the Arroyo Lencho Diego, where long faunal sequences were present in Purron and Abejas caves. The arroyo has sparse ground cover, mainly scatterings of lechugilla and stinging nettle (mala mujer). Tall tetecho, prickly pear, and organ cacti occur, and occasional tree legumes are seen on alluvial fans. The arroyo walls are barren rock, but the floors support a low thorn vegetation. Resources do not approach those of Subarea 3, and barrancas are normally dry.

White-winged doves, ameiva lizards, and black iguanas are the most frequently seen animals during the day; at night, striped skunks, Audubon cottontails, wood rats, and kangaroo rats are fairly common. The lack of ground cover would seem to inhibit the Mexican cottontail (*Sylvilagus cunicularius*), for few are found. The following animals were present.

MAMMALS

Sylvilagus audubonii
Cratogeomys sp.
Dipodomys phillipsii
Liomys irroratus
Peromyscus spp. (esp. *melanophrys*)
Sigmodon hispidus
Urocyon cinereoargenteus
Spilogale augustifrons
Mephitis macroura
Probably *Lynx rufus*

From caves:

Eptesicus fuscus
Neotoma alleni

In low frequency:

Sylvilagus cunicularius
Odocoileus virginianus

BIRDS

Zenaida asiatica
Caprimulgus ridgwayi
Chordeiles acutipennis
Tyto alba

REPTILES

Ctenosaura pectinata
Ameiva undulata

Faunal remains from archaeological sites in the Tehuacan Valley raise two points of interest regarding the prehistoric climate of the area. First, a somewhat colder late Pleistocene or immediately post-Pleistocene climate, ending before 7000 B.C., is suggested by remains of certain types of extinct fauna in the lowest levels of Coxcatlan Cave. Second, since the establishment of the present climatic regime and the disappearance of the now-extinct forms at the date mentioned above, there seem to have been no fluctuations which altered the fauna significantly.

The Early Ajuereado Climatic Phase

The lowest four zones (XXV-XXVIII) of Coxcatlan Cave in Subarea 3 yielded a fauna which differs from all subsequent levels in all sites excavated by the Tehuacan Project—including later Ajuereado phase levels, Zones XXIII and XXIV of Coxcatlan Cave. I would not be at all surprised to learn that a hiatus of some magnitude separated Zones XXIV and XXV at the latter site.

Since some 1200 identifiable bone fragments occur in the four zones of what I am calling the "Early" Ajuereado phase, the distinctness of the fauna cannot simply be due to sampling error. Both human hunting practices and true environmental differences are reflected in the bone collections. The Early Ajuereado fauna includes: (1) animals which are now extinct everywhere in the Western Hemisphere, and (2) animals whose range today lies considerably to the north of Tehuacan, in cooler (and often drier) regions. In spite of the large sample of bones, the Early Ajuereado collections lack some of the species which are most common in the area today, including all of the semitropical forms. And perhaps most significantly, the small rodent fauna of these lowest levels has a very different aspect from that of all subsequent levels in all sites in the sequence.

The precise age of these "Early Ajuereado" deposits is not known, but on the basis of radiocarbon determinations from later Ajuereado levels, they must antedate 7000 B.C. As far as the fauna itself goes, the deposits could be as early as 10,000 B.C. The period must be Late Peistocene or earliest post-Pleistocene, contemporary with the mammoth-kill sites in the valleys of Mexico and Puebla. Whatever their actual date, the Early Ajuereado faunal remains belong to a time when the Coxcatlan area was not the hot, semitropical, thorn-scrub forest it is today.

The Early Ajuereado Fauna

1. Included in the bone remains from Zones XXV-XXVIII are the following forms, no longer present in the Tehuacan region:

- Horse (*Equus* sp. indet.), 7 fragments
- Antelope (cf. *Antilocapra americana*), 45 fragments
- Large jack rabbits (*Lepus* sp. indet.), more than 700 fragments
- Large fox, more rugose than *Urocyon*, 49 fragments
- Small ground squirrel, chipmunk or prairie-dog size, 4 fragments
- Gopher tortoise (*Gopherus* cf. *berlandieri*), 102 fragments
- Quail, other than Bobwhite, 2 fragments

2. The following forms, common in the Coxcatlan area today, are totally absent in the Early Ajuereado remains:

- White-tailed deer (*Odocoileus virginianus*)
- Collared peccary (*Pecari tajacu*)
- Black iguana (*Ctenosaura pectinata*)
- Cotton rat (*Sigmodon hispidus*)
- Kangaroo rat (*Dipodomys phillipsii*)

3. The following forms are present today and were also represented in the Early Ajuereado debris:

- Audubon cottontail (*Sylvilagus audubonii*), less than 100 fragments
- Coyote (*Canis latrans*), 2 fragments
- Spotted skunk (*Spilogale* sp.), 4 fragments
- Striped skunk (*Mephitis* sp.), 4 fragments
- Hog-nosed skunk (*Conepatus* sp.), 1 fragment
- Ring-tailed cat (*Bassariscus* sp.), 4 fragments
- Rock squirrel (*Citellus mexicanus*), 4 fragments
- Wood rat (*Neotoma* spp.), 27 fragments
- Deer mouse (*Peromyscus* spp.), 21 fragments
- Spiny mouse (*Liomys* sp.), 1 fragment

The Early Ajuereado Rodents

The small wild mice and rats of the Early Ajuereado levels, like virtually all the rodents from caves in the Tehuacan Valley, appear to have been brought into Coxcatlan Cave in the form of owl pellets. For those who are not familiar with owl physiology, let us briefly explain this process.

Numerous of the local owls, especially the barn owl *Tyto alba*, use the caves of the Tehuacan Valley as nesting places. From these vantage points, the owls fly out at night and search for small rodents, finding and swallowing whole as many as they can. There is no evidence that owls discriminate against certain species of rodents, and hence their diet constitutes a random sample of the local rodent population. Owls swallow mice whole; the fleshy parts are dissolved by stomach acids, and then the fur forms a cocoon around the clean skeleton. This cocoon, known as an "owl pellet," is then regurgitated while the owl is roosting. Some caves in southern Mexico are covered by a carpet of disintegrating pellets.

Owls ccupied the Tehuacan caves during the periods between human occupations and left behind a stratified series of disintegrating pellets which were eventually incorporated into the human refuse. These constitute a series of random samples of the available

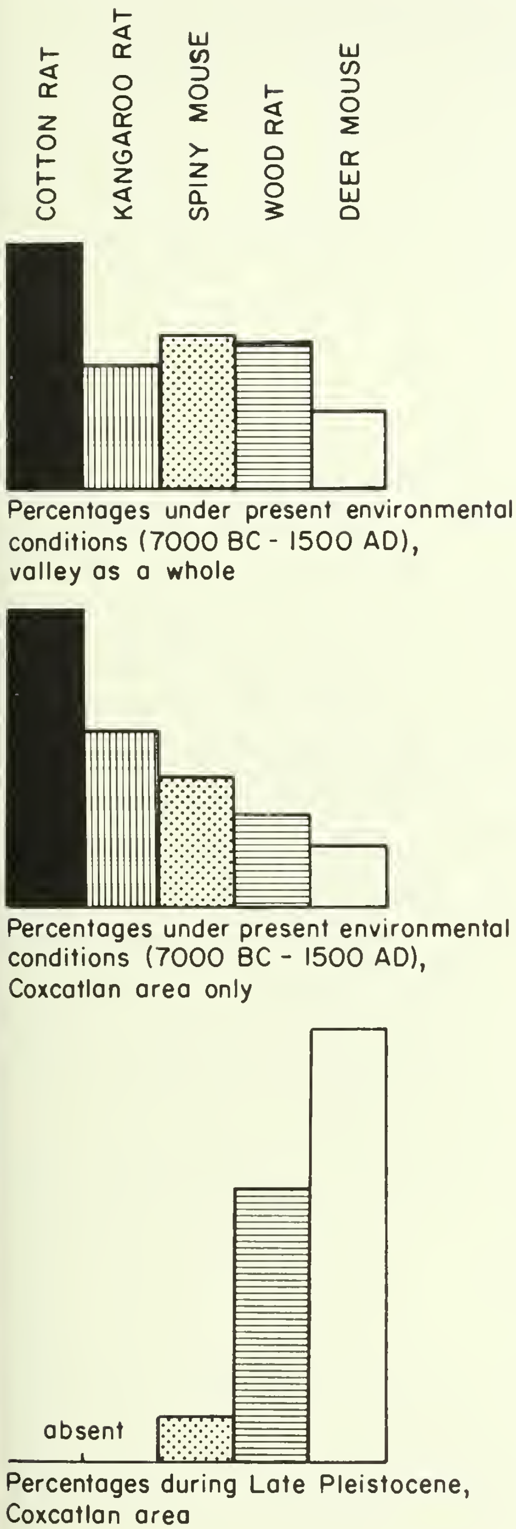

Fig. 94. Comparison of populations of small rodents. Percentages are based on minimum numbers of individuals of each genus.

rodent population during all periods of prehistory, an almost too-perfect situation for statistical analysis.

Because small rodents are more sensitive climatic indicators than most mammals, especially the larger ones, we found it useful to characterize the prehistoric environment by calculating the percentage each genus of rodent contributed to the whole sample from the owl pellets. Each subarea of the Tehuacan Valley has its own peculiar set of percentages, but the main five genera of small rodents are the same everywhere: only the proportions are different. From the Late Ajuereado phase until the present day, as revealed by owl pellet remains, the proportions of one type of rodent to another have remained fairly constant—a good indication that little environmental change has taken place. *Sigmodon hispidus*, the cotton rat, has increased, probably in response to increased agriculture and second-growth vegetation, but that is a not-unexpected situation; its range is still expanding northward across the United States into areas previously unoccupied (Hall and Kelson 1959: 671).

The small rodent population of the Early Ajuereado phase, however, is quite different from today's and quite different from all other prehistoric populations observed in owl pellet samples. Fig. 94 shows this in graphic form, and Table 15 and the briefer tabulation drawn from it give the figures on which the graph is based. We have compared the Early Ajuereado rodents, on the one hand, with the owl pellets from Coxcatlan Cave (Tc 50) only, and on the other hand, with the entire sample from all Tehuacan sites.

	Present Climatic Regime				*Late Pleistocene*	
	All sites		*Tc 50 only*		*Tc 50 only*	
Cotton rat (*Sigmodon*)	55	(225)*	29	(93)	——	
Kangaroo rat (*Dipodomys*)	27	(64)	17	(31)	——	
Spiny mouse (*Liomys*)	35	(138)	12	(22)	1	(1)
Wood rat (*Neotoma*)	33	(74)	9	(17)	7	(27)
Deer mouse (*Peromyscus*)	17	(37)	6	(7)	11	(21)

* Figures without parentheses are minimum numbers of rodents; figures in parentheses are numbers of identified bones.

Some 225 identifiable bones of cotton rat appeared in post-Pleistocene levels at Tehuacan. This is not surprising, for *Sigmodon hispidus*, wherever it occurs, tends to be the most numerous wild rodent in the region (Hall and Kelson, *loc. cit.*). It is today perhaps the most common wild rodent of Mexico and the southeastern United States. Yet, out of a sample of 50 identifiable rodent bones from the Early Ajuereado phase, *Sigmodon* is totally lacking.

Table 15. Small Rodent Remains from the Tehuacan Sites by Zone and Phase

	Deer Mouse									Wood Rat										Spiny Mouse								
												N. alleni		N. mexicana		Unspecified												
	individuals	total fragments	mummified corpse	skull or palate	ramus of mandible	innominate	femur	tibia	other	individuals	total fragments	skull or palate	r. mandible	skull or palate	r. mandible	innominate	femur	tibia	other	individuals	total fragments	mummified corpse	skull or palate	ramus of mandible	innominate	femur	tibia	other
Tc 35e, A	2	2		2						1	3	1	1				1			2	5		1	2		1	1	
Tc 50, I																												
Tc 50, II																				1	1					1		
Tc 35w, 3										1	2		1				1											
Tc 35e, B										1	1		1															
Tc 50, III																				1	1			1				
Tc 255, A	1	1					1			2	4		1			1	2			1	2					1	1	
Tc 35e, C	1	4		1	1		1	1		2	9			2	2	1	3	1		3	6		3	2				1
Venta Salada totals	4	7		3	1		2	1		7	19	1	4	2	2	2	7	1		8	15		4	5		3	2	1
Tc 35e, C-D (owl pellets)	3	18		3	4	4	4	3		3	10					4	4	2		10	88		10	15	19	19	20	5
Tc 35e, D																				1	3		1		1	1		
Tc 255, B										1	5	1	1				1	1	1									
Tc 35e, E																				1	1		1					
Tc 50, IV																				1	1						1	
Tc 254, B	1	1	1							1	4		2					1	1	1	4			1	1		2	
Tc 50, V																				1	3			1	1		1	
Tc 272, B	1	2			1		1			1	2	1						1										
Tc 272, E																				1	1	1						
Tc 50, VI																				2	4					2	2	
Tc 272, F										1	1					1												
Palo Blanco totals	2	3	1		1		1			4	12	2	3			1	1	3	2	8	17	1	2	2	3	3	6	
Tc 50, VII	1	2					1	1		2	6		1			1	4			1	3				1	1	1	
Santa Maria totals	1	2					1	1		2	6		1			1	4			1	3				1	1	1	
Tc 254, C[1]										1	1		1															
Ts 204, H																				1	3					2	1	
Ajalpan totals										1	1		1							1	3					2	1	
Tc 272, L																				1	2					2		
Tc 50, VIII										2	2						2			1	2					1	1	
Tc 50, IX										1	1		1															
Tc 272, N																												
Tc 254, D	1	1			1					2	3		1						2	1	1			1				
Tc 50, X	1	1					1			2	4		2				2			2	4					2	2	
Tc 272, P										1	4						1	2	1									
Abejas totals	2	2			1		1			8	14		4				5	2	3	5	9			1		5	3	
Tc 50, XI	1	1					1			1	3						2		1									
Tc 254, E	1	1			1					4	5		4					1										
Tc 254, F										1	2					1	1											
Tc 50, XII																												
Tc 272, Q																												
Coxcatlan totals	2	2			1		1			6	10		4			1	3	1	1									
Tc 50, XIV																												
Tc 50, XV																				1	2					2		
Tc 307, F																												
Tc 35w, 5																												
Tc 272, S										1	1		1															
Tc 50, XVIII	1	1					1																					
Tc 50, XIX	1	1					1			1	1						1			1	1						1	
Tc 50, XXII	1	1							1																			
El Riego totals	3	3					2		1	2	2		1				1			2	3					2	1	
Tc 35w, 6																												
Tc 50, XXIV																												
Late Ajuereado totals																												
Totals, Present Climatic Conditions	17	37	1	6	8	4	12	5	1	33	74	3	18	2	2	9	25	9	6	35	138	1	16	23	23	35	34	6
Tc 255, C (Mixed El Riego and Early Ajuereado)										2	3				2		1			1	1						1	
Tc 50, XXV	1	1					1			1	4	1	2						1									
Tc 50, XXVI	4	8			4		4			3	9			2?	1?		5	1		1	1						1	
Tc 50, XXVIII	6	12			7		2	2	1	3	14	1		2	2?		3	3	3									
Early Ajuereado totals	11	21			11		7	2	1	7	27	2	2	4?	3?		8	4	4	1	1						1	
Totals, all periods	28	58	1	6	19	4	19	7	2	42	104	5	20	6?	7?	9	34	13	10	37	140	1	16	23	23	35	36	6

(Minimum Numbers of Individuals Derived from Identified Fragments)

Kangaroo Rat								Cotton Rat								Harvest Mouse				Pygmy Mouse				
individuals	total fragments	skull or palate	ramus of mandible	innominate	femur	tibia	other	individuals	total fragments	skull or palate	ramus of mandible	innominate	femur	tibia	other	individuals	total fragments	skull or palate	ramus of mandible	individuals	total fragments	skull or palate	ramus of mandible	
1	3			1	2																			Tc 35e, A
								1	6		2	1	1	1	1									Tc 50, I
3	7				2	5		4	18	1	1	3	7	6										Tc 50, II
																								Tc 35w, 3
																								Tc 35e, B
2	4			2	2			2	8	1		2	2	2	1									Tc 50, III
1	1					1		3	10	1		4	4	1										Tc 255, A
1	2				2			2	10	2	2	1	3	1	1									Tc 35e, C
8	17			3	8	6		12	52	5	5	11	17	11	3									Venta Salada totals
3	21	3	3	5	5	4	1	8	63	7	16	9	11	12	8	1	3	1	2	1	2	1	1	Tc 35e, C-D (owl pellets)
								1	2				2											Tc 35e, D
								1	1					1										Tc 255, B
																								Tc 35e, E
1	2			1		1		6	15	1		3	8	3										Tc 50, IV
1	2				2			3	9		2		3	3	1									Tc 254, B
								2	10		4	1	2	2	1									Tc 50, V
								2	3			1	2											Tc 272, B
																								Tc 272, E
								5	25	5	7	2	5	4	2									Tc 50, VI
																								Tc 272, F
2	4			1	2	1		20	65	6	13	7	22	13	4									Palo Blanco totals
3	8				6	2		4	17		1	3	8	4	1									Tc 50, VII
3	8				6	2		4	17		1	3	8	4	1									Santa Maria totals
																								Tc 254, C'
																								Ts 204, H
																								Ajalpan totals
								1	1				1											Tc 272, L
								1	4		1	1	2											Tc 50, VIII
																								Tc 50, IX
								1	5				2	2	1									Tc 272, N
								1	2	1	1													Tc 254, D
1	1					1		2	5			1	3	1										Tc 50, X
								1	1				1											Tc 272, P
1	1					1		7	18	1	2	2	9	3	1									Abejas totals
								1	4		1		2	1										Tc 50, XI
1	2		1	1				1	2			1		1										Tc 254, E
																								Tc 254, F
1	1				1																			Tc 50, XII
								1	3	1	2													Tc 272, Q
2	3		1	1	1			3	9	1	3	1	2	2										Coxcatlan totals
1	3				2	1																		Tc 50, XIV
1	1				1																			Tc 50, XV
1	1					1																		Tc 307, F
1	1				1																			Tc 35w, 5
																								Tc 272, S
1	1				1																			Tc 50, XVIII
																								Tc 50, XIX
2	2					2																		Tc 50, XXII
7	9				5	4																		El Riego totals
								1	1				1											Tc 35w, 6
1	1				1																			Tc 50, XXIV
1	1				1			1	1				1											Late Ajuereado totals
27	64	3	4	10	28	18	1	55	225	20	40	33	70	45	17	1	3	1	2	1	2	1	1	Totals, Present Climatic Conditions
1	1					1																		Tc 255, C (Mixed El Riego and Early Ajuereado)
																								Tc 50, XXV
																								Tc 50, XXVI
																								Tc 50, XXVIII
																								Early Ajuereado totals
28	65	3	4	10	28	19	1	55	225	20	40	33	70	45	17	1	3	1	2	1	2	1	1	Totals, all periods

The second most common small rodent in the Coxcatlan area, and one of the most common in the valley as a whole, is the kangaroo rat, *Dipodomys*. It is also totally lacking in the Early Ajuereado sample.

The deer mouse, a prairie form which was never particularly abundant in post-Pleistocene owl pellets from the Tehuacan caves, constitutes 60 percent of the small rodents from the Early Ajuereado phase.

To check for the significance of these differences in percentages of small rodents, we ran a Difference of Proportions Test on *Sigmodon*, *Peromyscus*, and *Neotoma*. The test indicated that the chances that our Early Ajuereado rodent sample and our post-Pleistocene rodent samples from the Coxcatlan area came from the same population was less than 0.01 percent. In other words, the rodent population, and presumably the environment as well, were significantly different during the Early Ajuereado phase.

A Reconstruction of the Early Ajuereado Environment

Archaeologists have, on the average, tended to picture the Late Pleistocene as a cooler and moister period. This is not what is reflected in the Early Ajuereado fauna. If anything, it suggests that the Tehuacan environment may have been cooler and still more arid than today.

One way to reconstruct the environment is to look for an area which today contains a similar set of mammal species: large jack rabbits, antelope, small ground squirrels, gopher tortoise, lots of wood rats, and prairie deer mice. Today, such a complex can be found in the very arid interior plains of northern Mexico. Parts of western San Luis Potosi, eastern Zacatecas, and western Coahuila supported large antelope herds until the 1800's (Leopold 1959: 518), and are still rich in the smaller fauna characteristic of the Early Ajuereado phase.

This area today is open temperate steppe, with mesquite in the alluvial bottomlands and prickly pear on rocky slopes. In contrast to the Coxcatlan area, it receives winter frosts and lacks the dense vegetation of the arid tropical thorn forest. Its relative lack of underbrush and its open expanses of plains make it better habitat for antelope and jack rabbit than for white-tailed deer and cottontail, although the latter occur in the area.

This is how I would tend to reconstruct the Early Ajuereado environment. The valley floor would have been open steppe, grazed by horse and antelope, but to judge by the lack of cotton rats, it could not have had a very rich cover of tall weeds or grass. Both jack rabbits and wood rats like green leaves of mesquite, and wood rats are particularly abundant in groves of prickly pear (Schmidt-Nielsen 1964: 143–45). The absence of deer and possibly Mexican cottontail suggests that there was no real "forest" cover in the vicinity of Coxcatlan, and the absence of iguana suggests that winters were more severe than they are today.

Byers (Chapter 4 above) has suggested that during the last glacial period there may have been an equatorward displacement of the tropical and subtropical zones, giving southern Puebla a cooler and drier climate like that of San Juan sin Agua, in San Luis Potosi. Such a possibility is indeed supported by the Early Ajuereado fauna. Faunal remains, however, are a poor second choice to pollen analysis, and it is to be greatly regretted that pollen was not preserved, thus rendering impossible a palynological study of these early levels on which to base a somewhat more firm conclusion.

The Modern Climatic Regime

By at least 6500 B.C., according to radiocarbon dates, a completely modern fauna was present in the Tehuacan Valley. These dates are in accord with those from Frightful Cave, Coahuila (Taylor 1956), which show fully modern fauna by 6900 B.C. (M–191). The last of the extinct animals, of course, may not have been gone long; horse at Gypsum Cave, Nevada, was dated at 6567 B.C., and at Whitewater Draw, Arizona, occurred in levels dated at 6240 and 5472 B.C. (see Hester 1960: Table 5 for summary).

None of the lower levels at Coxcatlan Cave show a period of overlap during which outgoing antelope and incoming white-tailed deer shared the Tehuacan Valley. Either there is a real hiatus between Zones XXIV and XXV—which seems not unlikely—or else we are dealing with Hester's "Type 1" extinction, a "swift and total decline" for horse and antelope (1960: 58). Smaller forms such as fox and turtle were probably "replaced" by their modern counterparts, but the larger species vanished so abruptly that we are inclined to suspect that the unsuitability of their new environment was augmented by pressure from human hunting. As Leopold points out (1959: 523), antelope are "not particularly adept at keeping away from people, and hunting without regulation or control can easily exceed the productivity of the herds." The last of the dwindling antelope bands may simply have fallen victim to man, and the absence of deer bones in Early Ajuereado levels may only mean that prehistoric man found that hunting antelope on the open plain was easier and more productive than hunting deer in the bushy arroyos. At

the Levi Rock Shelter in Texas, white-tailed deer were already present at 8000 B.C. in levels containing extinct horse (Alexander 1963).

Once established, the present-day climatic regime held fairly constant. One good evidence of this is that after about 7000 B.C., as we have pointed out, the small rodents seem to have remained the same until the time of the Conquest. The five main forms are present from El Riego times on, which we take to mean that the basic ecology of the Tehuacan Valley has changed very little in the last 8500 years or so. Vegetal remains from the caves reportedly suggest the same stability of climate (see below, Chapter 12).

Systematics of the Tehuacan Fauna

What follows is not an exhaustive list of the fauna of the Tehuacan Valley. The object of this study was to compile data only on the edible mammals, reptiles, and birds of the region, and to concentrate especially on the habits and ecology of those species most relied upon by prehistoric man. Hence the "systematics" presented below are heavily skewed in favor of forms which served as food for the Indians of the Tehuacan Valley.

There are many more species of bats, insectivores, and possibly murine opossums than we collected, and we dealt only with the most common cricetid rodents. Among birds and reptiles, only a handful of species fell within the scope of our project. The list below presents the animals recovered in the order in which they are usually listed by zoologists; that is, phylogenetically.

Mammals

Order Marsupialia

FAMILY DIDELPHIIDAE

Didelphis marsupialis
(opossum; tlacuache)

Modern specimens collected: One adult male.

Measurements: Total length, 830 mm. Tail, 355 mm. Hind foot, 66 mm. Ear, 58 mm. Weight, 2.39 kg.

Present-day distribution: Opossums are distributed throughout the valley wherever there is even a trickle of water. They are particularly common in the Rio Salado–Rio Zapotitlan arroyos and the spring-fed irrigation canal system along the El Riego cliffs. Our specimen, shot near Venta Salada at midnight, June 21, 1962, was only one of dozens observed during night trips to the riverside in that area. Tracks are common at El Riego, where the animal was also well represented prehistorically. Opossums are, however, not at all frequent in the dry canyon areas or barren limestone plains.

Habits and diet: Callen's analysis of stomach contents of our specimen (see end of chapter) suggests a rainy-season diet including mesquite beans and insects of various kinds. These shy animals spend the day hidden in the underbrush and at night fall easy victim to traps or jack-light hunters.

Prehistoric distribution: Didelphis is represented as far back as about 6000 B. C. by a maxilla fragment from Zone XVII of Coxcatlan Cave (Subarea 3). It is most abundant in the remains from El Riego Cave, especially during the Palo Blanco and Venta Salada phases from 200 B.C. to the Spanish Conquest.

Marmosa canescens
(murine opossum; raton tlacuache)

Modern specimens collected: None.

Present-day distribution: Unknown.

Prehistoric distribution: The two archaeological occurrences of this tiny opossum suggested that they were brought into the cave by owls. A mandible and three limb bones found in a group of owl pellets in El Riego Cave dated to just before A.D. 700. Another mandible was found with a group of bat and small rodent remains in Zone II, Coxcatlan Cave (Venta Salada phase).

Order Chiroptera

FAMILY PHYLLOSTOMIDAE

Artibeus sp. (probably *jamaicencis*)
(fruit-eating bat; local name unknown)

Modern specimens collected: None.

Present-day distribution: Unknown, but probably ranges over all of the Tehuacan Valley.

Prehistoric distribution: One complete skull of *Artibeus* was found in Zone VI, Coxcatlan Cave (Palo Blanco phase).

FAMILY VESPERTILIONIDAE

Eptesicus fuscus
(brown-bat; local name unknown)

Modern specimens collected: Four specimens collected in August 1962 from caves in the El Riego cliffs were identified as *Eptesicus fuscus* by Dr. Bernardo Villa R. of the Instituto de Biología, Universidad Nacional Autonoma de Mexico.

Present-day distribution: Ranges over the whole of the valley.

Prehistoric distribution: A complete skull of *Eptes-*

icus was found in Zone II, Coxcatlan Cave (Venta Salada phase).

Order Lagomorpha

FAMILY LEPORIDAE

Lepus callotis
(white-sided jack rabbit; liebre)

Modern specimens collected: None.

Present-day distribution: Jack rabbits are restricted to open areas in the Tehuacan Valley, such as the barren saline steppe west of Venta Salada or the extensive cleared areas on top of the Mesa de El Riego. They are also found in the barren parts of the Zapotitlan hills and apparently occurred in moderate numbers on the valley floor itself before intensive agriculture and settlement confined them to the less inhabited areas.

Habits and diet: We observed jack rabbits foraging on the Venta Salada steppe at midnight, July 28, 1962. About five individuals were seen in an area roughly a kilometer square. The vegetation in the area is very short grass (kept so by sheep and goats) resting on a limestone-travertine terrace with almost no intervening soil. There are occasional tree legumes and weed patches in rain-filled depressions.

Prehistoric distribution: *Lepus callotis* is not known with certainty before the Coxcatlan phase. Its remains occur in Zone XI of Coxcatlan Cave and Zone 4 of El Riego Cave, West Niche, dating to roughly 4000 B.C. Jack rabbit remains are virtually lacking in thorn-forest zones such as Subarea 3.

Other Jack Rabbits

Numbers of very large rabbits, as yet unidentified, occurred in the Tehuacan Valley in association with extinct horse, antelope, small ground squirrels, and other fauna dating to the Early Ajuereado phase (Zones XXV–XXVIII, Coxcatlan Cave). These rabbits are too large to be cottontails; occasional diagnostic fragments suggest that they are jack rabbits, but not *Lepus callotis*. Because of the lack of comparative material, especially post-cranial, these rabbits have not yet been identified, but we wonder if they may not belong to the group of black-tailed jack rabbits still associated with antelope and small ground squirrel on the arid northern plains of Mexico.

Sylvilagus spp.

There are two species of *Sylvilagus* in the Tehuacan Valley, the Mexican cottontail and the Audubon cottontail. Their prehistoric distributions will be discussed together, because the character of the ecological subareas of the valley is somewhat reflected in the proportions of these two species one to another. The archaeological remains have afforded us a sample of cottontails spanning many centuries in all subareas.

The Audubon cottontail is an essentially arid temperate species whose range to the north reaches Montana (Hall and Kelson 1959: 267). The larger Mexican cottontail is more of an arid-tropical form, with a range extending south to the Isthmus of Tehuantepec and reaching only as far north as the state of Hidalgo, except for an arm extending up the Pacific coast lowlands to Sinaloa (Leopold 1959: Fig. 133). The ranges of these two species overlap in the Tehuacan Valley, where both are abundant and have been so for the last 9000 years. It would be interesting to know what factor enables both cottontails to live in the same area without competing, but so far we have no evidence except hints (see below) that there may be a dietary difference.

Sylvilagus audubonii
(Audubon cottontail; conejo chiquito)

Modern specimens collected: Two males and one female.

Measurements (range of three specimens): Total length, 345–365 mm. Tail, 30–41 mm. Hind foot, 80–90 mm. Ear, 63–65 mm. Weight, 0.8–0.9 kg.

Present-day distribution: Audubon cottontails are found throughout the valley, their populations being highest in relation to Mexican cottontails in areas of most barren ground and poorest soils, as in Subareas 2 and 4. The specimens we collected came from the Venta Salada plain, the Ajalpan plain, and fields near Calipan. A pregnant female, with two embryos, was taken June 27, 1962, at Venta Salada.

Habits and diet: During the rainy season, 1962, we observed local Audubon cottontails eating the young grass that sprouted after heavy rain. Callen's study, appended to this chapter, shows that they also ate corn plants and small fruits.

Sylvilagus cunicularius
(Mexican cottontail; conejo grande)

Modern specimens collected: One male and two females.

Measurements (of two adults, dimensions of male given first): Total length, 445 and 482 mm. Tail, 52 and 53 mm. Hind foot, 95 and 100 mm. Ear, 75 and 86 mm. Weight, 1.59 kg.

Present-day distribution: Mexican cottontails are found throughout the valley, populations being highest, in relation to Audubon cottontails, in areas of

densest ground cover and best-developed alluvial soils, such as the Rio Salado arroyo and most of Subarea 3. Our specimens all came from the Rio Salado floodplain near Venta Salada; one female, taken June 21, 1962, was pregnant, with four embryos.

Habits and diet: These animals are nocturnal foragers for grass as well as seeds and pods of tree legumes (see below). Our evidence is very scanty, but we wonder if these cottontails may not avoid competition with *S. audubonii* by eating somewhat different things within the same environment. They are, as mentioned above, particularly common on the kind of deep alluvial soils where mesquite and other tree legumes abound.

Prehistoric distribution of cottontails and jack rabbits: Some idea of the suitability of each subarea as a habitat for Mexican or Audubon cottontails is given by the prehistoric remains. Assuming that our cottontail sample for each period is random, it would appear that higher proportions of Mexican cottontails were present in Subarea 1 (both Ajalpan and El Riego localities) than in Subareas 2, 3, and 4. The accompanying tabulation ranks each of these habitats on the basis of percentages of Audubon and Mexican cottontails in the whole sample from a given prehistoric locality, under present-day climatic conditions (7000 B.C.–A.D. 1500). The gradient of Mexican cottontails, from 47 percent of the sample in the Ajalpan plain, near the Rio Salado, to only 16 percent in the dry Arroyo Lencho Diego, suggests that *S. cunicularius* was always more at home on the alluvial valley floor, while *S. audubonii* predominated heavily in areas of sparsest grass-and-weed-patch ground cover. Subarea 2 would probably have had the lowest Mexican cottontail population, were it not that our sample comes from Tecorral Canyon, a specialized and moister, more bushy niche within that subarea.

	Percent of Cottontail Sample	
Habitat	*Audubon*	*Mexican*
Subarea 1 (Ajalpan plain)	53	47
Subarea 1 (El Riego)	55	45
Subarea 2 (Tecorral Canyon)	65	35
Subarea 3 (Coxcatlan)	72	28
Subarea 4 (Arroyo Lencho Diego)	84	16

Order Rodentia

Family Sciuridae

Citellus (*Spermophilus*) *variegatus*
(grey rock squirrel; ardilla)

Modern specimens collected: One male.

Measurements: Total length, 480 mm. Tail, 205 mm. Hind foot, 59 mm. Ear, 24 mm. Weight, 0.80 kg.

Present-day distribution: There are no tree squirrels in the Tehuacan Valley, but rock squirrels in small numbers occur along the travertine cliff faces which mark off each step-like descent in altitude made by the Tehuacan Valley as one travels south. We collected one specimen from the El Riego cliffs and found a partial skeleton of another on the Ajalpan plain at Quachilco, not far from the rocky bluff where the Rio Zapotitlan enters the valley.

Habits and diet: The specimen we collected was shot in the afternoon, June 26, 1962. Its stomach contents (see below) revealed it had been eating cactus fruit and mesquite beans, as well as other plants.

Prehistoric distribution: Three limb bones of a large ground squirrel, probably *Citellus*, were found in Zones XXV and XXVI of Coxcatlan Cave in association with extinct horse, turtle, and antelope. The only other remains of this animal were limb bones in Zone A of El Riego Cave, East Niche (Venta Salada phase). Rock squirrels are still common in the El Riego area.

Small Ground Squirrel

There are no small ground squirrels in the Tehuacan Valley today, but a small Sciurid (which may be a prairie dog or a chipmunk) occurred in the Tehuacan Valley during the Early Ajuereado phase, in association with extinct horse and antelope.

Family Geomyidae

Gophers have never before been reported from the Tehuacan Valley. Archaeological remains, however, indicate that gophers have been present in the area for 7000 years. Prehistoric specimens fall into two categories: a large gopher whose bones are found in sites on the deep alluvial soils of the central valley floor, and a smaller gopher occurring in the shallower alluvium of narrow canyon floors in Subareas 2, 3, and 4. According to Señor Ticul Alvarez of the Instituto de Biología, who has examined these remains, it is probable that two unrecorded species of gophers are involved. His tentative identifications are as follows:

Heterogeomys sp. Found at sites in the Ajalpan and El Riego plains, generally in Subarea 1. This is the larger of the two gophers.

Cratogeomys sp. Found in caves located on dry barrancas with shallow alluvial bottoms such as occur in Subareas 2, 3, and 4.

Family Heteromyidae

Dipodomys phillipsii
(kangaroo rat; raton canguro)

Modern specimens collected: Two females.

Measurements: Total length, 255 and 260 mm. Tail, 150 and 170 mm. Hind foot, 37 and 39 mm. Ear, 13 mm. Weight, 38 and 42 gms.

Present-day distribution: This is one of the more common mammals in the Tehuacan Valley, both on the valley floor and in the thorny barranca areas. Night after night we observed these small rodents foraging for seeds. We found their burrows on the barren Venta Salada steppe, the hills in front of Coxcatlan Cave, and west of Ajalpan on an open alluvial plain with occasional mesquite trees. Our specimens, both lactating females, were collected from Subareas 1 and 3 on July 4 and 14, 1962.

Habits and diet: Kangaroo rats are apparently active all year at Tehuacan; we observed them in the hearts of the rainy season (July) and dry season (January). They were mainly active between 9:00 P.M. and midnight, but some could still be seen at 3:00 A.M. on favorable nights.

Prehistoric distribution: This rodent has been in the Valley since at least 6800 B.C. (Zone XXIV, Coxcatlan Cave). It has always been most common in Subarea 3 (see Table 15).

Liomys irroratus
(spiny mouse; local name unknown)

Modern specimens collected: Three.

Measurements: Tail, 125 mm. Hind foot, 28 mm. Ear, 14 mm. Length and weight could not be taken.

Present-day distribution: The three specimens were taken from the stomach of a female bobcat (*Lynx rufus*) shot at midnight, July 8, 1962, near Venta Salada. They constitute our only record of *Liomys*.

Habits and diet: The three mice had apparently been active at midnight on the alluvial plain near the Rio Salado, for their cheek-pouches contained seeds of various kinds, among them mesquite and prickly pear (see below).

Prehistoric distribution: Archaeological specimens of spiny mice are found in all caves located near alluvial soils which will support tree legumes. Highest populations probably existed in Subarea 1, both on the Ajalpan plain and on the well-watered alluvium near El Riego. *Liomys* was scarce or absent in Subarea 2 except for alluvial canyon floors (see Table 15). Scattered specimens were found in all subareas. In the Coxcatlan region *Liomys* was contemporary with extinct horse and antelope.

Family Cricetidae

Reithrodontomys fulvescens
(harvest mouse; local name unknown)

Modern specimens collected: None.

Present-day distribution: Known to occur from Teotitlan to Tepanco, north of Tehuacan (Hall and Kelson 1959: 592–93).

Prehistoric distribution: *Reithrodontomys* is found in owl pellets from El Riego Cave, dating to about A.D. 700.

Peromyscus spp.

Remains of *Peromyscus* were found in virtually all caves in all subareas, but it was not always possible to determine which species was present. Both *P. leucopus* and *P. melanophrys* are definitely known to be present in the Tehuacan area (Miller and Kellogg 1955: 491, 503), and it is probable that many other species occur there also. Remains of *Peromyscus* are more common in the levels with extinct horse and antelope than in any of the more recent levels. They appear in small frequency, however, in all subareas throughout the archaeological sequence (see Table 15).

Peromyscus melanophrys
(deer mouse; local name unknown)

Modern specimens collected: One female.

Measurements: Total length, 240 mm. Tail, 140 mm. Hind foot, 24 mm. Ear 24 mm. Weight 38 gms.

Present-day distribution: This mouse is known from Tehuacan, Teotitlan, and Cuicatlan (Miller and Kellogg, *loc. cit.*).

Habits and diet: Deer mice were observed mainly between 9:00 and 11:00 on moonless nights, and even then their presence was unpredictable. On some nights (for example, July 23, 1962) they seemed to be everywhere, especially in the branches of mesquite trees (*Dipodomys* was abundant terrestrially on this same night). On other nights, hardly a deer mouse could be seen. Our specimen collected near Coxcatlan Cave at midnight August 2, already had a stomach full of insects (see below), which it had been hunting on a mesquite-and-cactus alluvial apron at the head of a long barranca leading down from the cliffs to the Rio Salado.

Baiomys musculus
(pigmy mouse; local name unknown)

Modern specimens collected: None.

Present-day distribution: Known from Teotitlan and Tepanco in the Tehuacan Valley (Hall and Kelson 1959: 661).

Prehistoric distribution: Our only find of *Baiomys* was a palate and a mandible in owl pellets from El Riego Cave, dating to about A.D. 700.

Sigmodon hispidus
(cotton rat; local name unknown)

Modern specimens collected: None.

Present-day distribution: Throughout the valley; especially common in the southern half.

Prehistoric distribution: Cotton rats were present in the Tehuacan Valley almost from the beginning of the present climatic regime. Their remains go back to Zone 6 in the West Niche of El Riego Cave (before 6500 B.C.) and Zone Q in Purron Cave (before 4300 B.C.). Remains are not really common, however, until about 1000 B.C., after which time they are abundant in Subareas 3 and 4 (see Table 15). Owl pellets dating to about A.D. 700 (see below, p. 156) suggest that during that period cotton rats may have constituted about 28 percent of the small rodents in the vicinity of El Riego Cave.

Neotoma spp.

Wood rats were present in the Tehuacan Valley as far back as our record goes; they are particularly common in canyon areas (see Table 15). At least two different species are known through archaeological remains.

Neotoma mexicana
(Mexican wood rat; local name unknown)

Modern specimens collected: None.

Present-day distribution: *N. mexicana* may be the most common wood rat in the northern or arid-temperate part of the valley, but it is largely replaced or outnumbered by *N. alleni* in the southern part, according to evidence from the uppermost levels of the caves.

Prehistoric distribution: During the Early Ajuereado phase, *N. mexicana* reached Subareas 3 and 4 in large numbers, contemporary with extinct horse and antelope; it is also possibly found in association with antelope bones in the lowest levels of Tecorral Cave (Subarea 2). After the transition to present-day climatic conditions, as the southern half of the valley gradually became arid-tropical, *N. mexicana* may have retreated to the north, for it is absent from cave deposits laid down since 7000 B.C. in Subareas 3 and 4 but is present in deposits later than that date in El Riego Cave in Subarea 1.

Neotoma alleni
(Allen's wood rat; local name unknown)

Modern specimens collected: None.

Present-day distribution: *N. alleni* may be the most common wood rat in the southern or arid-tropical part of the Tehuacan Valley; it is outnumbered in the northern end by *N. mexicana*, according to data from uppermost levels in the Tehuacan caves. It has been previously collected at Tehuacan and Teotitlan (Hall and Kelson 1959: 706).

Prehistoric distribution: Allen's wood rat has been present in Subarea 3 since the Early Ajuereado phase. Its remains occur throughout the valley, in all subareas, from the time of extinct horse and antelope until the Spanish Conquest.

The accompanying tabulation shows the suitability of various habitats within the Tehuacan Valley for the five main genera of small rodents recovered from the caves. The figures represent the percentage each genus constitutes of the total sample of the five genera from archaeological sites in each subarea for the period 7000 B.C. to A.D. 1500.

Habitat	*Cotton rat*	*Deer mouse*	*Spiny mouse*	*Wood rat*	*Kangaroo rat*
Subarea 1 (El Riego)	25	12	35	16	12
Subarea 2 (Tecorral Canyon)	29	13	10	38	10
Subarea 3 (Coxcatlan)	39	8	17	12	24
Subarea 4 (Arroyo Lencho Diego)	43	7	14	29	7

Order Carnivora

FAMILY CANIDAE

Canis latrans
(coyote)

Modern specimens collected: One male and one female.

Measurements (dimensions of male are given first): Total length, 1130 and 1016 mm. Tail, 300 and 280 mm. Hind foot, 190 and 183 mm. Ear, not measurable; hides had been cut off. Weight, not taken; specimens had been fleshed and gutted.

Present-day distribution: In the Cerro El Zapote area of Subarea 3 reportedly five coyotes per month are

sighted. They are hunted on the hills east of Chapulco today. Members of the Tehuacan Project saw coyote feces at various places and observed a coyote cross the highway near Zapotitlan in April 1963. We were also offered a young specimen from the Rio Salado thickets near Ajalpan, captured in July of 1962. Probably the major coyote populations surviving in the valley today are in Subareas 3 and 4.

Habits and diet: The two coyotes we collected were shot on successive nights during the week prior to December 24, 1962, while they were attempting to break into a sheep pen in the thorn forest on the slopes of Cerro El Zapote, near Coxcatlan.

Prehistoric distribution: Coyotes were present in virtually all subareas in prehistoric time; however, their remains are more frequent in the most ancient levels. In Subarea 3 and perhaps in Tecorral Canyon, their remains are found with those of extinct horse and antelope.

Canis familiaris
(domestic dog; perro)

Modern specimens collected: one female, from Coxcatlan.

Measurements: Total length, 980 mm. Tail, 260 mm. Hind foot, 164 mm. Ear, 100 mm. Weight, 8 kg.

Present-day distribution: Throughout the valley.

Prehistoric distribution: Domestic dog first appears in the Tehuacan sequence at the start of the late preceramic Abejas phase. Our earliest records of it are teeth and mandibles, dating to about 3200 B.C. in Coxcatlan Cave and to about 2500 B.C. in Purron Cave. Dogs increase in frequency during the early and middle Formative periods, after which they are common in all levels in all subareas. In most cases there is abundant evidence that they were being eaten, at least as early as 1500 B.C. That dogs are definitely not present earlier, in spite of the large sample of bone remains from the period before 3000 B.C., suggests that dogs were not kept in the Tehuacan Valley until a level of considerable agricultural efficiency had been reached. They are, in other words, characteristic of the early village farming stage but of no previous period. The romantic concept that dog was man's faithful companion during the stage when man was a hunter and gatherer seems to be completely inaccurate as far as the Tehuacan Valley is concerned.

Urocyon cinereoargenteus
(gray fox; zorro gris)

Modern specimens collected: One, incomplete; no measurements.

Present-day distribution: A fresh skull and mandible of this fox were collected in May 1962 along the trail from the highway to Coxcatlan Cave (Subarea 3). A hide was purchased in the Ajalpan market in June 1962 by Arturo Arvide of the Tehuacan Project. The only live specimen sighted was seen at 8:00 A.M. by its burrow near the banks of the Rio Zapotitlan, just upstream from its confluence with the Rio Salado. All three occurrences suggest that dens are probably in the more nearly forested parts of the valley, either in thorn forest (Subarea 3) or in the quebrachales and cane thickets along the main watercourses, but the animal ranges over the whole valley at night.

Habits and diet: Mainly nocturnal and extremely shy, this fox is probably much more common in the Tehuacan Valley than our limited records show. We got no stomach contents from collected specimens, but these foxes are relatively omnivorous (Leopold 1959: 410). They probably make use of the abundant rodents and wild fruits in Subarea 3 and the river arroyos.

Prehistoric distribution: Remains which are clearly those of *Urocyon cinereoargenteus* are found in sites in all subareas dating from at least 6500 B.C. to the Spanish Conquest.

Extinct Fox

Remains of a fox whose bones are considerably larger and more rugose than those of *Urocyon* were found in Early Ajuereado levels, contemporary with extinct horse and antelope.

Family Procyonidae

Bassariscus astutus
(ring-tailed cat; cacomixtle)

Modern specimens collected: One female.

Measurements: Head and body, 430 mm. Tail, 330 mm. (bitten off in a fight). Hind foot, 79 mm. Ear, 45 mm. Weight, 1.59 kg.

Present-day distribution: Our only record of ring-tailed cat during 1962 was the specimen mentioned above, shot at night on June 30 by a farmer in the Barranca de los Mangos near Calipan. The animal had apparently descended to the edge of the valley floor from the foothills above Calipan and was feeding on mesquite beans and insects (see below). Nothing further is known of the distribution of this comparatively rare nocturnal animal in the Tehuacan area.

Prehistoric distribution: The only archaeological record of *Bassariscus* comes from the Early Ajuereado phase (Zone XXVI of Coxcatlan Cave), found in association with extinct fauna.

Procyon lotor
(raccoon; mapache)

Modern specimens collected: One male.

Measurements: Total length, 800 mm. Tail, 270 mm. Hind foot, 120 mm. Ear, 60 mm. Weight, 5.0 kg.

Present-day distribution: The distribution of raccoons in the valley follows the watercourses regardless of subarea. We observed their foot tracks along wet barrancas both in forested mountain areas and between nearly barren limestone cliffs. They are not uncommon in the El Riego springs area. We collected a specimen from the Barranca de los Mangos near Calipan, where the animals reportedly collect when the cultivated fruit trees are bearing. Raccoon is not one of the most prevalent animals in the region, however, probably because of the extensive waterless stretches in the valley.

Habits and diet: The male we collected was discovered at 5:00 A.M. on July 2, 1962. His intestinal contents indicated a dinner of cactus fruit and insects (see below).

Prehistoric distribution: Our oldest record of *Procyon* in the Tehuacan area comes from Zone X of Coxcatlan Cave in Subarea 3, dated to about 3200 B.C. Certainly raccoons must have been present earlier, but not being as common as some of the other small mammals, they probably were not as often taken by prehistoric hunters. Remains were frequently found in village sites located near the Rio Salado.

FAMILY MUSTELIDAE

Spilogale augustifrons
(spotted skunk; zorrillo manchado)

Modern specimens collected: None.

Present-day distribution: Unknown, but recent archaeological remains suggest *Spilogale* is far commoner in the canyon areas of Subareas 2, 3, and 4 than in the center of the valley, where *Mephitis* is prevalent.

Prehistoric distribution: *Spilogale* is a contemporary of extinct horse and antelope in the lowest levels of Coxcatlan Cave. It is present during all phases in all caves located in canyon areas, especially Coxcatlan and Tecorral. It is not known from any of the sites located in the Apalpan plain.

Mephitis macroura
(hooded or striped skunk; zorrillo rayado)

Modern specimens collected: One female.

Measurements: Total length, 615 mm. Tail, 330 mm. Hind foot, 60 mm. Ear, 30 mm. Weight, 0.9 kg.

Present-day distribution: Striped skunks are common in all parts of the Tehuacan Valley, but nowhere did they seem quite as abundant to us as in the center of the valley and in the thorn-scrub forest near Coxcatlan Cave. Hardly a night trip to Subarea 3 failed to produce a sighting of one or two skunks, whose immediate reaction to our flashlights was to bound off into the brush with a warning wave of the tail. Our specimen, pregnant with two fetuses, was collected near Calipan, June 22, 1962.

Habits and diet: Beetles and beetle larvae apparently make up a good percentage of this animal's diet (see below), although according to Leopold (1959: 459), it is less dependent on these foods than is the hog-nosed skunk. We found *Mephitis* foraging by night along the cut-away banks of dry arroyos and on the talus slopes below cliffs.

Conepatus mesoleucus
(hog-nosed skunk; local name unknown)

Modern specimens collected: None.

Present-day distribution: Unknown, but probably more common in the pine and oak forest above the valley than in the valley itself.

Prehistoric distribution: *Conepatus* is represented by mandibles and other fragments in Coxcatlan Cave during the Early Ajuereado phase. Scattered finds occur throughout the sequence, especially in Subarea 3.

FAMILY FELIDAE

Felis concolor
(puma or mountain lion; leon)

Modern specimens collected: None.

Present-day distribution: Unknown, but Frederick A. Peterson of the Tehuacan Project sighted a puma in the thorn forest near Coxcatlan Cave in 1961. Today the puma is almost extinct in the area.

Prehistoric distribution: Puma bones were found in Zone XXII of Coxcatlan Cave (El Riego phase) and in Zone D[1] of Las Canoas village site, near Ajalpan (Santa Maria phase).

Lynx rufus
(bobcat; gato montes)

Modern specimens collected: One female.

Measurements: Total length, 715 mm. Tail, 140 mm. Hind foot, 148 mm. Ear, 69 mm. Weight 4.55 kg.

Present-day and prehistoric distribution: Nothing is known of the present-day distribution of the bobcat in the Tehuacan region beyond the occurrence of the specimen mentioned above. This would seem to be

one of the most southerly occurrences of *Lynx rufus* on record (cf. Hall and Kelson 1959: 970). Leopold (1959: fig. 182) does not extend its range farther south than the Valley of Mexico, and he comments (p. 484) on the puzzling scarcity of bobcats in south-central Mexico in spite of the occurrence there of habitats resembling those in which this species thrives in northern Mexico: areas combining brush, rocky canyons, and abundant rodents. The Tehuacan Valley is such an area, and bone fragments from Zone XXI of Coxcatlan Cave (El Riego phase) indicate that bobcats have been present there for at least 8000 years. Subareas 1 and 3, with their high rodent populations, probably were and are its preferred habitat.

Habits and diet: The female bobcat we collected was shot at Venta Salada northeast of the confluence of the Rio Salado and Rio Zapotitlan. It had been hunting spiny mice (*Liomys irroratus*), and three of the latter were recovered from its stomach, each neatly bitten in half (see above).

Order Perissodactyla

FAMILY EQUIDAE

Equus sp. (extinct horse)

Prehistoric distribution: Remains of horse occur in the lower three zones (XXVI–XXVIII) of Coxcatlan Cave, and date to before 7000 B.C. Some of these remains match bones of extinct horse from the Pleistocene gravels in the Valsequillo area of the Valley of Puebla (Arenillas locality), collected by Professor Juan Armenta.

Order Artiodactyla

FAMILY TAYASSUIDAE

Pecari (*Tayassu*) *tajacu*
(collared peccary; javali, coche de monte)

Modern specimens collected: One male from the valley of the Rio Calapilla.

Measurements: No measurements were taken by the hunters, who ate the flesh but saved us the bones (December 20, 1962).

Present-day distribution: The collared peccary is virtually extinct within the Tehuacan Valley floor area today, but survives in the nearly uninhabited drainage of the Rio Calapilla.

Prehistoric distribution: Archaeological records show the peccary present, though never really abundant, for 8000 years or more in all subareas with sufficient surface water. Highest prehistoric populations seem to have been in the Rio Salado thickets, the El Riego area, and Subarea 3.

FAMILY CERVIDAE

Odocoileus virginianus
(white-tailed deer; venado cola blanca)

Modern specimens collected: None.

Present-day distribution: White-tailed deer are extremely rare in the Tehuacan Valley today, owing to the pressure of year-round hunting. Relict populations exist in the surrounding hills, however, especially in Subarea 3 and in the valley of the Rio Calapilla. To the south, across the Oaxaca border near Teotitlan del Camino, hunters in December of 1962 reportedly killed four or five.

Prehistoric distribution: That *Odocoileus* was once common in the valley is well documented archaeologically. Over 1500 identifiable fragments of deer, the remains of at least 174 individuals, testify to its presence as far back as 7000 B.C., by which time it had apparently replaced antelope as the most common artiodactyl of the area. Highest prehistoric deer populations appear to have been in the forested river arroyos and in the thorn-forest cover of the Coxcatlan-Calipan area, as well as the area of the El Riego springs; they were evidently scarce in Subarea 2, even in the wetter barrancas.

FAMILY ANTILOCAPRIDAE

Remains of antelope were present in the four lowest zones (XXV–XXVIII) of Coxcatlan Cave. Because we had no well-studied comparative material at hand in Tehuacan, we could not determine whether the remains were those of now-extinct Pleistocene antelope or simply represented a southerly subspecies of the American prong-horn *Antilocapra americana*, but it is probably the latter. These antelope had apparently disappeared from the Tehuacan Valley by 7000 B.C.

Reptiles

The Tehuacan Valley has a rich variety of reptiles, but only those eaten by man today or apparently eaten prehistorically were studied. Hence this short list is culturally determined, and in no sense reflects the reptilian ecology of the valley.

Order Chelonia

FAMILY KINOSTERNIDAE

Kinosternon integrum
(mud turtle; tortuga, galápago)

Modern specimens collected: One male and one female.

Measurements (dimensions of male are given first): Length of carapace, 155 and 135 mm. Weight with shell, 0.5 and 0.5 kg. Weight of turtle alone, 0.35 and 0.30 kg.

Present-day distribution: As far as I was able to establish, this is the only turtle living in the Tehuacan Valley today. It is restricted to the Rio Salado and its tributaries, just as is the green iguana (see below). One of our specimens, a female, was collected in the Rio Salado at 2:00 P.M. on July 27, 1962, during a light drizzle, at which time it was actively engaged in eating water bugs. The male turtle was recovered at 5:00 P.M. on July 28 while buried in the mud at the bottom of a small pond on a spring-fed tributary stream of the Rio Salado, near Venta Salada.

Habits and diet: The female had been eating aquatic insects and snails (see below). The male had been feeding on leafy plants around the margins of the tributary pond. Local villagers report that they have seen these animals leave the water to eat carrion, but I cannot document this. The female was gravid, with 11 eggs. The male (an elderly specimen) had a thick layer of mossy vegetation adhering to the top of his carapace, which may aid in camouflage.

Prehistoric distribution: These small turtles have been used as a source of food since about 5000 B.C. in the vicinity of the Rio Salado and its tributaries. This includes Tecorral Canyon, which is presently dry for most of the year, but which, on the basis of abundant prehistoric mud-turtle remains, may have had a more reliable flow of water in ancient times. Turtle scutes are most frequent in sites near Ajalpan, along the banks of the Rio Salado, especially during the period from 1500 to 500 B.C.

Pleistocene Turtle?

Remains of a much larger turtle were abundant in the four lowest zones of Coxcatlan Cave (XXV–XXVIII) and in Zone C of Tecorral Cave in association with antelope. Much of the fragmentary material has not been firmly identified, but the horny cover from an anterior vertebral scute found in a later level (and presumably redeposited) at San Marcos Cave appears to be *Gopherus berlandieri*. The Texas gopher tortoise is precisely the type of turtle one would expect to share a steppe environment with horse, jack rabbit, and antelope in the Early Ajuereado phase.

Order Squamata

Family Iguanidae

Iguana iguana
(green iguana, iguana verde)

Modern specimens collected: One male.

Measurements: Total length, 1160 mm. Tail, 780 mm. Hind foot, 145 mm. Weight, 2.45 kg.

Present-day distribution: This is a basically tropical-forest species whose presence in the arid Tehuacan Valley is quite surprising. It is restricted to the arroyos of the Rio Salado, Rio Zapotitlan, and Rio Calapilla, presumably using them as the corridor through which it originally entered the valley from the Veracruz coast, by way of the Rio Santo Domingo. To the best of my knowledge, this iguana is not known as far north as the city of Tehuacan under present-day conditions. Today, the green iguana survives in the southern part of the valley, confining its activities to the most humid local environments, where it lives on the moist vegetation of the river bank.

Habits and diet: The specimen we collected near the Rio Zapotitlan was active at noon June 20, 1962. Its stomach contained only the leaves of tree legumes.

Prehistoric distribution: Unknown.

Ctenosaura pectinata
(black iguana, ground iguana; iguana negra, iguana pinta)

Modern specimens collected: Three.

Measurements (one adult specimen): Total length, 790 mm. Tail, 500 mm. Hind foot, 75 mm. Weight, 1 kg.

Present-day distribution: This is the most common iguana in the Tehuacan Valley. One of our specimens was caught near Ajalpan, while foraging along the alluvial plain among mesquite trees. *Ctenosaura* is not restricted to wet areas as is *Iguana* and ranges over most of the southern part of the valley, especially in the dry canyons around Purron Cave (Subarea 4) and Coxcatlan Cave (Subarea 3). It is also found in the Rio Salado thickets west of Coxcatlan, and at the base of the travertine cliffs on the west edge of the valley near the point where the Rio Zapotitlan breaks through to enter the valley floor. These animals are common from Ajalpan south, but we have yet to discover them above the 1600-meter contour.

Habits and diet: These iguanas are active mainly during the rainy season, at which time they roam widely; they can also be observed late in the dry season, when they tend to stay closer to their burrows.

They bite when cornered and sometimes will attempt escape by climbing low trees, although they seem to be mainly terrestrial. Our Ajalpan specimen was active at 3:30 P.M., June 18, 1962. The amazing range of diet revealed by Callen's study (see below), including fruit, insects, and spiders, makes the omnivorous character of this animal seem one key to its widespread distribution. Comments by some authors (Smith 1946: 34; Schmidt and Inger 1957: 118) that *Ctenosaura* is exclusively vegetarian would seem not to apply to this Mexican species. Ditmars (1940: 28), in his description of *Ctenosaura multispinis*, states that captive black iguanas "will take young birds and small rodents and are surprisingly agile in catching the prey . . . In a wild state [black iguanas] are undoubtedly carnivorous to a considerable extent."

This iguana has several color phases. Although it is almost always black when adult, it is often piebald or covered with gray-white or pinkish-gray patches when young. Because of this, local villagers believe that there are two ground-dwelling iguanas in the Tehuacan Valley.

Prehistoric distribution: Black iguanas appear in archaeological deposits in Purron Cave (Subarea 4) and Coxcatlan Cave (Subarea 3) as far back as 500 B.C.

FAMILY TEIIDAE

Ameiva undulata
(large race-runner lizard; lagartija)

Modern specimens collected: Five.

Measurements (one adult): Total length, 386 mm. Tail, 250 mm. Hind foot, 50 mm. Weight, 110 gms.

Present-day distribution: During the summer these race-runners are abundant throughout the valley, especially on barren rock faces such as the El Riego cliffs below La Mesa. They can also be observed scurrying along the valley floor in open areas like the Ajalpan plain.

Habits and diet: These race-runners seem to be active in the valley during the rainy season, from May to September, when their insect food sources are most abundant. On a single day in July one may see hundreds on the El Riego cliffs, and on a return visit to the same spot in December may not see a single individual. When present, the race-runners are most active during the hot part of the day, skimming over the rocks with blinding speed. Stomachs which I examined indicate a diet of small insects and arachnids, including June beetles and pseudoscorpions.

Prehistoric distribution: These lizards have been present since the beginning of present-day climatic conditions. Their bones are found in Zone XXIV at Coxcatlan Cave (before 6500 B.C.). From then until the Conquest, remains of *Ameiva* are found in all subareas, and are useful rainy-season indicators. The types of parts discarded and the kind of charring observed on some of the bones indicate that these lizards were eaten by the valley's prehistoric inhabitants.

Birds

This study makes no attempt to do justice to the varied bird life at Tehuacan. Since our principal problem was the diet of prehistoric man, we concerned ourselves only with the local game birds, or other birds occasionally eaten in the area.

FAMILY ANATIDAE

Anas cyanoptera
(cinnamon teal; pato)

Modern specimens collected: One female.

Measurements: Folded wing, 177 mm. Tail, 58 mm. Tarsus, 34 mm. Bill, 40 mm. Weight, 340 gms.

Present-day distribution: Ducks are scarce today in the Tehuacan Valley, this being the only species with which the present-day residents are familiar. One specimen donated to the project was shot in flight near the Pueblo Nuevo dam on the Rio Salado at ten o'clock on a slightly overcast winter morning, December 21, 1962. The area backed up by the dam is a pond surrounded by swampy alluvium full of marsh grass, *palo de agua*, and other plants. It is flanked by mud flats which end at the three-meter-high banks of earth and gravel setting the river off from the nearby hills. The ducks share this environment with the American egret (*Casmerodius albus*).

Habits and diet: These ducks arrive in the Tehuacan Valley in November, and the few that survive the winter hunting season leave sometime in February. The largest flock we saw contained fifty individuals, but groups of five to ten are far more frequent.

Prehistoric distribution: Unknown.

FAMILY PHASIANIDAE

Colinus virginianus
(bobwhite quail; codorniz)

Modern specimens collected: One male.

Measurements: Folded wing, 110 mm. Tail, 62 mm. Tarsus, 33 mm. Bill, 15 mm. Weight, 150 gms.

Present-day distribution: Bobwhites are common in weed patches along the Rio Salado and in areas where ground cover is fairly dense, such as the underbrush

around the El Riego springs or the floor of the Tecorral Canyon. Our specimen is from Ajalpan.

Habits and diet: These quail are active daily in overgrown cornfields and other weedy areas, collecting seeds of various kinds (see below).

Prehistoric distribution: Quail have been eaten during all of Tehuacan prehistory, but specimens indistinguishable from the bobwhite do not occur until Zone XXIII of Coxcatlan Cave (about 6500 B.C.). Their remains are found through all subsequent periods, particularly at sites in Subareas 1 and 3.

Family Meleagridae

Meleagris gallopavo
(domestic turkey; pavo)

Modern specimens collected: One male.

Present-day distribution: Virtually everywhere in the valley. Our specimen is from Coxcatlan.

Prehistoric distribution: Domestic turkey bones first appear in the Tehuacan sequence early in the Palo Blanco phase, about A.D. 180 (Zone VI, Coxcatlan Cave). Thereafter turkeys increase in number, and by the time of the Conquest constitute about 10 percent of the animals eaten in the valley, according to archaeological remains. There is no evidence of the wild turkey at Tehuacan during any period, and it is unlikely that its range ever extended that far south (see Leopold 1959: 268–71).

Family Charadriidae

Charadrius vociferus
(killdeer; chichicuilote)

Modern specimens collected: One from the Rio Salado.

Present-day distribution: Killdeer are common along the banks of the Rio Salado during the winter, and are occasionally killed for food by local villagers.

Prehistoric distribution: Unknown.

Family Columbidae

Zenaida asiatica
(white-winged dove; paloma de alas blancas)

Modern specimens collected: Five.

Measurements (average of five): Folded wing 162 mm. Tail, 107 mm. Tarsus, 26 mm. Bill, 24 mm. Weight 150 gms.

Present-day distribution: These doves are among the most common birds in the valley and are found in every environmental subarea. They can be seen roosting on cacti in the most barren areas or perched high in the branches of the river-bank trees, from one end of the valley to the other. We collected specimens from thickets along the Rio Salado, from the thorn forest at Coxcatlan Cave, and from open cornfields south of Ajalpan. Local villagers collected scores of others for their own tables.

Habits and diet: White-winged doves are active all year in the Tehuacan Valley, for surprisingly long stretches daily. They eat a wide variety of foods (see below). Specimens we collected in the Rio Salado quebrachales at noon on June 20 had been eating tree fruits; others had been eating cactus fruits; and one, captured as late as 10:00 P.M. on July 25, had been eating cutworms. The doves seemed to be almost as active at 10:00 that night as they had been at 10:00 in the morning.

Prehistoric distribution: *Zenaida* has figured in the food supply of man for almost as long as we have any record of human habitation in the Tehuacan Valley. Zone XXII of Coxcatlan Cave (after 6500 B.C.) contained a humerus of this genus, and there are many other occurrences at all time periods in all subareas. Most of these dove bone fragments match perfectly with modern skeletons of *Zenaida asiatica*, and it may be that most (if not all) of them are white-winged doves or some closely related species.

Columbigallina passerina
(ground dove; paloma canela, "torito")

Modern specimens collected: One from Venta Salada.

Present-day distribution: These doves are common throughout the Tehuacan area, not only on the valley floor but also in the streets and plazas of the villages.

Prehistoric distribution: Fragments of ground dove were uncovered in Zone XV of Coxcatlan Cave (about 5000 B.C.). Later finds are sporadic and cannot always be specifically assigned to *Columbigallina passerina*.

Family Tytonidae

Tyto alba
(barn owl; tecolote grande)

Modern specimens collected: None.

Present-day distribution: Throughout the valley, nesting occasionally in caves.

Habits and diet: A large clutch of owl pellets was found in the East Niche of El Riego Cave, interpolated between Zones D and C and dating to just before A.D. 700. Their contents give us a look at the diet of barn owls in the El Riego area at that time. The remains in-

cluded ten spiny mice (*Liomys irroratus*), eight cotton rats (*Sigmodon hispidus*), three deer mice (*Peromyscus* spp.), three kangaroo rats (*Dipodomys phillipsii*), three wood rats (*Neotoma* spp.), one harvest mouse (*Reithrodontomys fulvescens*), one pigmy mouse (*Baiomys musculus*), one murine opossum (*Marmosa canescens*), one juvenile gopher, two juvenile cottontails (*Sylvilagus* sp.), and one small bird. Since the climatic conditions about A.D. 700 were not strikingly different from those of today, the modern diet of *Tyto* in the El Riego area is probably similar to the list above.

Prehistoric distribution: A tibia and tarsometatarsus of *Tyto alba* were found in Zone XI of Coxcatlan Cave (roughly 4000 B.C.). Owl pellets probably attributable to *Tyto* are common in El Riego Cave, and in most cases it seemed likely that this owl was the animal responsible for bringing small rodents into the caves.

Family Caprimulgidae

Caprimulgus ridgwayi
(buff-collared nightjar, Ridgway's whippoorwill; lechuza)

Modern specimens collected: One.

Measurements: Folded wing, 160 mm. Tail, damaged. Tarsus, 24 mm. Bill, 22 mm. Weight 43 gms.

Present-day distribution: This bird is a very common nocturnal inhabitant of the valley, from El Riego to Coxcatlan. During the day it can often be surprised while nesting on the ground under mesquite trees and bushes along the valley floor.

Habits and diet: One specimen collected at Coxcatlan Cave at dusk (7:10 P.M.) on July 30, 1962, had been eating a variety of local insects (see below).

Prehistoric distribution: Unknown.

Chordeiles acutipennis
(lesser nighthawk; lechuza)

Chordeiles is also common in the valley, but no specimens were collected.

Family Corvidae

Corvus corax
(raven; cacalote)

Modern specimens collected: One.

Measurements: Folded wing, 405 mm. Tail, 221 mm. Tarsus, 82 mm. Bill, 76 mm. Weight, 1 kg.

Present-day distribution: Very common throughout the valley.

Habits and diet: Our specimen, collected June 20, 1962, just south of Ajalpan, had been eating corn, lizards, and a variety of insects (see below).

Prehistoric distribution: Remains of ravens from as early as 1500 B.C. were recovered at village sites in the Ajalpan area.

The Pre-Columbian Faunal Remains

Nearly 11,000 bones or fragments of bones were recovered from the archaeological excavations in the Tehuacan Valley. These bones included 4,713 skeletal components which could be identified both as to type of animal and part of skeleton. The remaining fragments were too incomplete to identify, being mostly splinters or flakes from the shafts of long bones which preserved no portions of the articular surface or any other diagnostic attribute. Fairly accurate rough counts were kept on these unidentifiable fragments, and each was examined for signs of butchering technique.

The 4,713 identified components represented the remains of at least 1,013 individual animals (see below). Most of these were animals eaten by the prehistoric inhabitants of the valley, some were small rodents deposited in the caves via owl pellets, and others were fully-articulated uneaten animals which had either

	Minimum no. of animals	*No. of skeletal components*	*Unidentifiable fragments (round nos.)*
Animal food remains			
Coxcatlan Cave and Terrace	381	2,555	4,000
Purron and Abejas caves	79	233	300
Tecorral and San Marcos caves	57	180	100
El Riego Cave (East and West)	109	416	250
Ajalpan, Coatepec, Las Canoas, and Quachilco	178	683	1,100
Animals not used as food			
Small rodents (all sites)	192	597	150
Other intrusive animals	17	49	—
Totals	1,013	4,713	5,900

been buried in the cave or died there of natural causes. Some, in the uppermost levels of the caves, had been completely mummified by the dry Tehuacan climate. Counts of all these categories of animals are given in the accompanying tabulation.

All identifiable fragments of bone were checked against one or more of the following collections: (1) skeletons of animals which I collected in the Tehuacan Valley and other regions of southern Mexico and in Guatemala; (2) skeletal material in the collections of the Instituto de Biología, Universidad Nacional Autonoma de Mexico, Mexico City; (3) skeletons of Mexican animals in the collections of the Chicago Natural History Museum; and (4) fossil collections from Valsequillo, Puebla, at the Museo de la Revolución in the city of Puebla.*

Once all the identifiable bones from a given natural level or zone at a particular site had been checked, an effort was made to determine the minimum number of individuals present for each species. This was done by the method worked out by White (1953: 397), who suggests:

> The method I have used in the studies on butchering technique is to separate the most abundant element of the species found (usually the distal end of the tibia) into right and left components and use the greater number as the unit of calculation. This may introduce a slight error on the conservative side because, without the expenditure of a great deal of time with small return, we cannot be sure all of the lefts match all of the rights.

This method is coming to be used increasingly by other faunal analysts (see Lundelius' study in Alexander 1963: 513), and we gave it only a slight modification: we expended the "great deal of time with small return" in order to see if all the lefts matched all the rights. Frequently they did not, and our figures were hence changed. The most common difference observed was one of age—that is, the lefts might all be from very juvenile animals, while the single right was from an aged individual, and so on.

For deer, we used studies like those of Villa (1954), which allowed us to measure age on the basis of tooth and antler development. Thus we could reason with justification that the many-tined antler of a three-year-old buck, found in a given level, could not belong to the deer represented in the same level by a mandible with an as-yet-unerupted first molar, since this tooth comes through at an age of six months; two deer had to be present. We were cautious with antlers, knowing that man might bring back shed specimens to the cave for tool-making, and only accepted an antler if we could find fragments of its unshed base. Shed antlers were not counted in the animal remains. Thus our estimates of "minimum number of individuals" for each species are the result of a number of approaches to the problem, done with care and (we hope) overlooking as little as possible.

Still other methods were used in order to determine the season of the year during which a given zone was deposited. Some animals, like the large race-runner lizards (*Ameiva*) common along the El Riego cliffs, are active only during the rainy season; when their bones were present, we guessed that the level had been laid down sometime between June and September. Animals probably traceable to winter or dry-season occupations included the sandhill crane, which today visits Mexico from November to April and summers in the United States and Canada, although in the past it may have nested in Mexico (see Leopold 1959: 281; Martin del Campo 1944).

Other seasonal evidences were derived from deer antlers and even deer fetuses, the latter of which were not uncommon in Coxcatlan Cave. Villa's studies on time of antler drop by deer from Mexico show, as pointed out by Leopold (1959: 512), that "the first bucks to lose their antlers seemed to be those from the south —Oaxaca and Guerrero—where the breeding season is earlier." February, March, and possibly early April appear to be the usual months during which Villa's southern specimens lost their antlers; new ones began to appear during April and May. Through the rainy season the antlers were in velvet, and by the end of October they had reached their "forma decidua definitiva," fully grown and ossified right to the end of the tines (Villa 1954: 459). Regarding bones of fetal deer, we relied on Leopold's assembly of figures (1959: 510–11), which suggest that from Chihuahua to Guerrero the time of fawning may vary from June to September. Roughly the same time period would be the one to which late-term fetuses might be attributed, and we

* I was greatly aided in this study by other zoologists, including specialists in small rodents and birds, two categories with which I was unfamiliar. Professor Bernardo Villa R. kindly allowed me access to collections at the Instituto de Biología, where Sr. Ticul Alvarez identified many of the small rodents from the Tehuacan caves. Two visiting American ornithologists, Allen Phillips and Robert Dickerman, took time from their busy schedules to identify bird bones. Study of the Chicago Natural History Museum collections was made possible by Drs. William Turnbull and Philip Hershkovitz, and more of our Tehuacan rodents were identified there by Dr. Joseph Moore. Professor Juan Armenta of the Universidad Autonoma de Puebla allowed us to examine fossil mammals from the Valsequillo gravels. My grateful thanks go to these men for the role they played in making this paper possible.

have accordingly done so, especially since there was a good correlation between bones of fetal deer and bones of *Ameiva* lizards in rainy-season levels.

One final word of caution for the reader: the percentages given for certain species of animals in the total remains from a level, used in the discussion below, are not to be taken too literally. They are calculated from very small samples and should serve only as a rough guide to the activities and food preferences of a given period.

The Sequence from Coxcatlan Cave and Terrace, Subarea 3

For a variety of reasons, Coxcatlan Cave lies in perhaps the best hunting locality in the Tehuacan Valley, and the bone remains reflect this. From its vantage point in the Cerro Agujereado, 975 meters above sea level, this big rock shelter looks north over a rolling mountain talus covered with the densest thorn forest observed in the whole valley system. To the east is a high sierra, also covered with scrub thorn, which gives way to pine and oak forest some 500 meters above the cave. To the west, over a low ridge of hills, lie the valley floor and the wide arroyo of the Rio Salado, hidden by quebrachales and dense stands of cane. Hunters camped at Coxcatlan Cave could have foraged in the Venta Salada area and returned home in half a day, or ascended to the pine and oak vegetation belt to cut maguey or hunt deer and peccary. The platform of the cave gives an unobstructed view of many square miles of varied country. Some brief mention of the fauna of Subarea 3 has been made above and we will only repeat here that almost all the animals found in the Coxcatlan area occur in the immediate vicinity of the cave.

Early Ajuereado Phase

Irregular occupation levels in the yellow rock-dust at the bottom of the shelter yielded the bones of animals either extinct or no longer present in the Tehuacan Valley. The implications of this fauna in terms of paleo-climate have been discussed above. This was a period which in most of North America is rather inadequately labeled "paleo-Indian," there being usually so little evidence concerning human subsistence pattern during the period that no more descriptive term can be used. The lower four zones of Coxcatlan Cave show that during this period, which occurred before 7000 B.C. and possibly as early as 10,000 or 9000 B.C., man in the Tehuacan Valley ate considerable amounts of small game. Sixty-nine of the individual animals recovered from the Early Ajuereado phase are rabbits. Perhaps eighteen of these are small rabbits which appear to be Audubon cottontails. The others are much larger, and certainly are jack rabbits, but since they differ from the forms found in the Tehuacan Valley today, I did not feel secure enough in my identification to break them down into fine categories. Hence, all these animals are presented in Table 16 simply as "Late Pleistocene rabbits," with the comment that they are mostly jack rabbits. Present but not so abundantly represented are coyotes, foxes, skunks of three kinds (spotted being the most common, with striped and hog-nosed skunks in second and third places), ring-tailed cats, large rock squirrels, small ground squirrels (which may be either prairie dogs or chipmunks), and quail and other birds. One hundred and two scutes, representing at least seven turtles of a large type no longer present in the area, also appeared in the debris, as did fragments of snake and lizard. Less than 10 percent of the individual animals were horses and antelopes, the large fauna usually so abundant in "kill sites" from this period (see, for example, Hester 1960).

The finding of great piles of foot bones of jack rabbit in a few excavated squares of the cave suggests that these extremities were often trimmed off and discarded all in one corner of the occupation floor. Antelope were probably brought back intact to the rock shelter, judging by the variety of bones found, which included ribs, vertebrae, inner ears, and other head components. We are not equally sure that horses were brought back intact, since our sample of bones of this species is too small to be conclusive. Long bones of the larger animals are not badly smashed as they often are in later periods, and many of the long bones of the smaller animals are completely unbroken, although occasionally they are charred.

Late Ajuereado Phase

This period is characterized by tools of the same type as Early Ajuereado, but a completely modern fauna seems to be present. White-tailed deer are now being hunted and represent about 40 percent of the individual animals recovered. Rabbits have dropped to 30 percent, and all specimens are the Audubon and Mexican cottontails common in the valley today. Bobwhite quail, ameiva lizards, and hog-nosed skunks round out the remains from Late Ajuereado levels.

The presence of hardened antler tines (in their October–February condition), fragments of fetal deer (probably from the May to August period), and such rainy-season indicators as ameiva lizard suggest that the Late Ajuereado occupations at Coxcatlan Cave represent camps made during several seasons of the year.

El Riego Phase

This is the most abundantly represented phase in Subarea 3, with ten zones from Coxcatlan Cave and Terrace. Over 400 identified bones of deer, representing the remains of at least forty-two individuals of all ages and both sexes, show that white-tails were about 40 percent of the animals eaten in this area during the El Riego phase. Cottontails constituted 35 percent of the individual animals, and we have evidence of three peccary, three foxes, both spotted and hooded skunks, one mountain lion, one bobcat, and two opossums. A mud turtle was brought to the cave (possibly from the Rio Salado), and ameiva lizards were collected, probably in the vicinity of the cave. Several doves were eaten, as well as quail and songbirds. In Zones XVIII and XX, in a rainy-season context, fragments of large fish were found. Since no fish of this size exists in the Tehuacan Valley today, we can neither identify it nor explain it, except to hazard a guess that the Rio Salado flowed deeper then than it does today, or that its sloughs were more extensive.

All seasons are represented in the faunal debris, and some of the occupations must have been quite long. Zone XXI of Coxcatlan Cave contained fragments of deer fetus and hardened antler, suggesting a camp made during the late rainy and/or early dry seasons. Zones XX and XIX both have enough ameiva lizard remains to brand them as rainy-season occupations. Three more zones from this phase were so large that they could be subdivided into separate occupations which took place within a short span of years. Zone XVIII had an extremely large dry-season occupation in its east end, with the remains of three deer of different ages, two cottontails, a skunk, and a songbird, while the west half of the same zone, a rainy-season camp, had fish, lizard, dove, three cottontails, and a spotted skunk, as well as three deer whose remains indicated they had been brought intact to the rock shelter.

The pattern in Zone XVI was somewhat similar. Debris in the west end of the cave shows that this part of the zone was a dry-season camp, with bones and hardened antler tines of deer and many fragments of cottontail. The east half of this same zone had extensive refuse from all seasons of the year, including ameiva lizards and fragments of fetal deer (May to September), full hardened antlers ripped from the frontal bone (October to February), and a spongy, only partially-developed antler which had been in velvet when the deer was killed (April to June?).

In Zone XV, the east half of the rock shelter showed the butchered remains of at least three deer, plus fragments of a fetus carried by one of the does, which indicated a late rainy-season camp; remains of cottontail and fox were also found in this half. In the western part of the same zone lay the debris from another rainy-season camp where deer, cottontails, and birds had been eaten. Zone XIV was an extremely large occupation divided into an east section, and upper-west and lower-west sections. All seasons of the year are represented, with dry-season indicators mostly confined to the bottom part of the zone, and spring or rainy-season indicators present principally in the upper part.

There is more evidence of the prehistoric butchering technique in El Riego phase levels than in any other phase in this subarea. In the case of deer, virtually every part of the body is represented, from long bones and hooves down to skull components, which are seldom preserved in Tehuacan sites—fragments of zygomatic arch, hyoid, squamosal, occiput, rim of the orbit, and others. Also present are bits of sternum, rib, vertebra (even some from the base of the tail), and blade of the scapula, which has convinced us that the entire carcass was brought intact to the rock shelter. The long bones of the deer during this phase (and especially between Zones XIX and XIV) are smashed to a degree that could not have happened accidentally, even under conditions of heavy rock fall. Hundreds of fragments are no larger than a toothpick, and all have been splintered by heavy percussion blows. This bone-splintering technique is unlike anything found in the other phases at Coxcatlan Cave, and it undoubtedly reflects extensive use of bone marrow. Most deer long bones show some sign of roasting before the marrow was extracted.

Our hypothetical reconstruction of El Riego butchering technique, based on fragments of bone, cut marks, type of skeletal components found and their condition, is as follows. First, the entire carcass of a deer was brought back to the cave and laid out on the floor. The hide was then removed, the last few tail vertebrae being carried away with it. Next the animal was gutted and, if it was a pregnant doe, the fetus removed. If the deer was a buck, the antlers were removed by breaking them away from the frontal bone, and later (sometimes) these were cut up into antler hammers and tine pressure-flakers. The shoulder joint must have been cut through with heavy cleavers, for the upper end of the humerus is virtually never found. A blow just above the distal end of the metapodial separated the feet, which were often discarded as a unit. After the meat had been cut off, the long bones were roasted and then systematically pounded into splinters with heavy stone tools so the marrow could be completely extracted.

Table 16. Food Animals from Coxcatlan Cave and Terrace (Subarea 3) by Zone and Phase

	Early Ajuereado				Late Ajuereado		El Riego										Coxcatlan			Abejas				Sta. Maria	Palo Blanco				Venta Salada			
	Tc 50, XXVIII	Tc 50, XXVII	Tc 50, XXVI	Tc 50, XXV	Tc 50, XXIV	Tc 50, XXIII	Tc 50, XXII	Tc 50, XXI	Tc 50, XX	Tc 50, XIX	Tc 50, XVIII	Tc 50, XVII	Tc 50, XVI	Ts 51, D-E	Tc 50, XV	Tc 50, XIV	Tc 50, XIII	Tc 50, XII	Tc 50, XI	Tc 50, X	Ts 51, C	Tc 50, IX	Tc 50, VIII	Tc 50, VII	Ts 51, A,B	Tc 50, VI	Tc 50, V	Tc 50, IV	Tc 50, III	Tc 50, II	Tc 50, I	Totals
Extinct Horse (indivs.)	1	1	1																													3
Fragments	2	1	4																													7
Antelope (indivs.)	1	1	2	3																												7
Ramus, mandible	1																															1
Teeth		2	3																													5
Petrous bone			3	4																												7
Scapula	1																															1
Radius				1																												1
Innominate	1		2																													3
Tibia			1																													1
Metapodial			3	1																												4
Phalanx	2		9	4																												15
Other	1		6																													7
White-tailed Deer (indivs.)					2	2	2	2	2	4	6	1	9	2	6	8	2	3	9	4	1	3	2	4	1	2	2	2	1	2	1	85
Antler					1	1		1	1	1	1		4		2	3		2	5	1			2	3								28
Teeth					2		1					3	8				1	5	7					2			1	1				31
Ramus, mandible							1	1	2	4	5		5		4	7	1	3	6	4		2	1	4	1	2		2		2		57
Petrous bone										7	2	1	6		4	11	2	2	8	2				2			1	1			1	50
Scapula						1				2			3	1	1	2		1	2	2		1	2					1				19
Humerus							1	3		1		1	4		4	3	1		4	2		1		3							1	29
Radius					1	1	2	1	1	2	7	1	16	1	5	6	1	2	9	1		2	3	2		2			2			68
Ulna					2		1	2		3	1		8		7	3	3	3	9	6				2		1		1			1	53
Innominate									2		1	1	1			1			2					3								11
Femur								1	1		2		3		2	4	1	1	3	1		2	1	1		1	1	1	1			27
Tibia					1		1		2	3	3	1	6	1	4	10	1	4	6	1		2	1	3		2		1		1		54
Calcaneum					1			1					2	1	2				5	5	1	1		3		3						25
Astragalus					1	1		1		2	5	1	7		2	4		1	10	5	1	3		4				3				51
Naviculocuboid							1			2	1				3		1	1	4	1		1		2		2		1				20
Metapodial					2	4	3	4	3	3	10	3	15		11	17	3	6	22	6	1	5	7	8		6	2	1	1		1	144
Phalanx					1	1				1	4		1	2	1	6		3	15	10		4		10		8	2	2	2			73
Vertebra					2	2	1	3		1	1	1	1	1	5	6		3	15	8	1	6	2	6		7		1				73
Rib					1	1	2	3	5		1		3		2	1		2	5			5	2	2		6		6			3	50
Other						2		2	2	3	3		7		4	7			6	5		6		6		5		2	1	3	1	65
Frags. foetus					1	2		2							4							3				1	3	1	2		2	21
Peccary (indivs.)							1		1						1				1	1				1		1						7
Maxilla															1											1						2
Ramus, mandible																										2						2
Scapula																			1													1
Humerus									1																							1
Tibia							1																									1
Astragalus																				1						1						2
Metapodial							1																	1								2
Phalanx																				1				1								2
Other																			2													2
Late Pleistocene Rabbits (indivs.)	8	5	40	16																												69
Maxilla	4	2	21	2																												29
Ramus, mandible	4	1	24	4																												33
Humerus	8	5	42	16																												71
Radius	8	3	18	14																												43
Ulna	9		22	7																												38
Innominate	11	7	63	16																												97
Femur	4	3	35	16																												58
Tibia	3	5	47	20																												75
Calcaneum	8	2	27	29																												66
Other	45	5	100	140																												290
Recent Cottontails (indivs.)					2	1	2	2	2	3	5	1	10		4	6	1	3	6	2		2	1	7		4	2	2	2	2		72
Maxilla								1		1	3		2		2	3		1				1		8			2					24
Ramus, mandible					1		1		1		4		6		4	7	1	4	2			2	1			3		2	1			40
Humerus						1						1	1		1	1		1	1	3		1				3						14
Radius						1				1									2	1									1			6
Ulna					1	1	1				2	1	1					1				1		1				1				11
Innominate					1			1	1	3	4	1	6		1	4	1		4	1		4		2		2	1	2				39

(*Minimum Numbers of Individuals Derived from Identified Fragments*)

	Early Ajuereado				Late Ajuereado		El Riego										Coxcatlan			Abejas				Sta. Maria	Palo Blanco				Venta Salada			
	Tc 50, XXVIII	Tc 50, XXVII	Tc 50, XXVI	Tc 50, XXV	Tc 50, XXIV	Tc 50, XXIII	Tc 50, XXII	Tc 50, XXI	Tc 50, XX	Tc 50, XIX	Tc 50, XVIII	Tc 50, XVII	Tc 50, XVI	Ts 51, D-E	Tc 50, XV	Tc 50, XIV	Tc 50, XIII	Tc 50, XII	Tc 50, XI	Tc 50, X	Ts 51, C	Tc 50, IX	Tc 50, VIII	Tc 50, VII	Ts 51, A,B	Tc 50, VI	Tc 50, V	Tc 50, IV	Tc 50, III	Tc 50, II	Tc 50, I	Totals,
Recent Cottontails (cont.)																																
Femur					1	1	1			1	1		2		1	2	1		5				1	4		1	2	1		2		27
Tibia					1			1		3	1		5		2	3			3			3		3								25
Calcaneum								1		1									1	1												4
Other					1			1	4	11		3	1		5	3		1	6			1	2	3		10	2	1	1	1		57
Recent Jackrabbit (indivs.)																			1													1
Fragments																			1													1
Coyote (indivs.)			1	1																												2
Fragments			1	1																												2
Fox (indivs.)	1	1	3	1						1		1			1			1				1				1	1	1	1	1		16
Fragments	9	5	26	9						2		1			1			2				1				3	3	1	2	3		68
Skunk (indivs.)	2		4		1						2								1				1	1	1	2	1		1	1		18
Fragments	3		6		1						2								2				3	3	1	4	2		2	1		30
Ring-tailed Cat (indivs.)			1																													1
Fragments			4																													4
Rock Squirrel (indivs.)			1	1																												2
Fragments			1	3																												4
Prairie Dog or Chipmunk (indivs.)	1		1	1																												3
Fragments	1		1	2																												4
Puma (indivs.)							1																									1
Fragments							1																									1
Bobcat (indivs.)								1																					1			2
Fragments								1																					3			4
Opossum (indivs.)													1			1															1	3
Fragments													1			1															1	3
Raccoon (indivs.)																				1												1
Fragments																				1												1
Gopher (indivs.)																												1			1	2
Fragments																												1			1	2
Dog (indivs.)																				1						1	1	2		2	1	8
Fragments																				1						1	1	5		3	1	12
Extinct Turtle (indivs.)	1	1	2	3																												7
Fragments	16	1	33	52																												102
Mud Turtle (indivs.)																1																1
Fragments																1																1
Snake (indivs.)	1																															1
Fragments	1																															1
Iguana (indivs.)																								1		1				1	1	4
Fragments																								1		6				8	3	18
Other Lizards (indivs.)	2?	1	6?	3?	1				1	1	1			1		2		1						2		1	1			1	1	26?
Fragments	27	2	90	45	1				1	7	1			1		2		1						4		2	1			1	1	187
Quail (indivs.)			1			1									1																	3
Fragments			2			1									1																	4
Dove (indivs.)							1		1		1				1								1					1				6
Fragments							1		1		1				1								1					1				6
Song-birds (indivs.)											1															1						2·
Fragments											1															1						2
Crane (indivs.)																	1															1
Fragments																	1															1
Barn Owl (indivs.)																			1													1
Fragments																			2													2
Raven (indivs.)																											1	1				2
Fragments																											1	2				3
Hawk (indivs.)																													1	1		2
Fragments																													1	1		2
Turkey (indivs.)																										1				1	1	3
Fragments																										1				4	1	6
Other Birds (indivs.)	3	1	3		1														1					1		2			2	1		15
Fragments	4	1	4		1														1					1		2			2	1		17
Fish (indivs.)									1		1								1			1										4
Fragments									1		1								1			1										4

Coxcatlan Phase

The zones occupied during this phase are interesting, in that most are dry-season camps. During at least one of these dry-season occupations, deer appear to have been intensively hunted. In fact, for the whole of the phase in the Coxcatlan area, deer represent about 43 percent of the individual animals recovered. Cottontails account for 30 percent, and other animals include peccary, fox, and spotted skunk. During the Coxcatlan phase several species of birds, including the barn owl and a very large bird tentatively identified as a sandhill crane, were included in the diet. Probably the presence of crane in Zone XIII reinforces our evidence for a dry-season occupation, for these birds tend to winter in southern Mexico. Both Allen Phillips and Robert Dickerman, who examined the specimen, stress caution in the matter of seasonality in view of a find of sub-fossil crane eggs in the Valley of Mexico (Martin del Campo 1944), which suggests these cranes may have stayed for the summer nesting season occasionally in the past.

Once again, deer seem to have been brought whole to the rock shelter for butchering, but during this phase there is no evidence of the meticulous smashing of long bones seen in El Riego times. Some bones, in fact, seem to have been discarded while still articulated with their neighbors and held together with ligaments—especially bones of the lower leg like the metatarsal, astragalus, naviculocuboid, calcaneum, and others. The entire foot of a Mexican cottontail was found discarded while still articulated in Square E15 of Zone XI, and an articulated elbow-joint of Audubon cottontail was found in Zone XII. Once the feet were trimmed off, these smaller mammals appear to have been roasted over hot coals (which produced a rather spotty charring pattern) and the limbs then eaten as units with no disjointing of their individual components.

A shift to predominantly dry-season occupations after the end of the El Riego phase is suggested by the lack of ameiva lizards and the numbers of hardened or "winter-season" antlers, coupled with an absence of the deer fetuses so abundant in El Riego times. That intensive deer hunting was one phase of this dry-season activity is suggested not only by the nearly 200 identifiable fragments of white-tail in these three zones of Coxcatlan Cave, but also by large numbers of projectile points, including a number of types new to this phase (see Volume II: The Nonceramic Artifacts).

Abejas Phase

This phase is characterized by intensive deer hunting, equal to that of the Coxcatlan phase. The zones are primarily dry-season occupations, where hunting far outweighed trapping. Further, the introduction of the domestic dog took place early in this period. The latter first appears in Zone X, dated about 3200 B.C., and stands therefore as the oldest evidence of domestic dog in Mesoamerica proper. Dog remains occur also in the Abejas phase of Purron Cave, as will be noted below. In both cases the evidence involves teeth which matched well with dog specimens in our collections and differed drastically from those of the only other large canid in the area, the coyote. Abejas dogs were much smaller than coyotes, probably weighing only ten to fifteen pounds.

Forty-five percent of the individual animals recovered from Abejas levels at Coxcatlan Cave and Terrace were deer, with cottontails representing only 23 percent and the difference made up by peccary, fox, hog-nosed skunk, and raccoon. The occupants of these levels also ate doves and did some fishing. This represents the last evidence of fish in the prehistoric sequence in the Tehuacan Valley.

The entire carcasses of deer were still brought to the rock shelter, but there are larger numbers of intact, unsmashed long bones in this phase than in any of the preceding ones. Less frugal wringing of nourishment from deer was noted in the bone debris, probably because agricultural products were beginning to represent a significant part of the food supply. For the first time, some bones appear to have been cut part way through with stone blades and then snapped. This may be related to the fact that prismatic obsidian blades make their first appearance during Abejas times (see Volume II).

Santa Maria Phase

A hiatus in the Subarea 3 sequence follows the abandonment of Zone VIII in Coxcatlan Cave. Then comes Zone VII, a heavy occupation during the later Formative Santa Maria phase. Three divisions of the zone, into a west half and upper and lower east sections, give differing evidences of seasonality. The west half is a rainy-season camp during which the occupants trapped cottontails and spotted skunk, hunted deer and peccary, and ate iguana and ameiva lizards. The lower part of the east half of Zone VII, containing bones of ameiva lizards, was a rainy-season camp with little sign of hunting, while the upper part had many deer bones, including antlers from bucks taken during the dry season. Trapping of rabbits would seem to have been more intensive during the occupation of the west-end rainy-season camp; deer hunting was more intensive during

the occupation in the east end (probably because a dry-season camp was included here, if we are to judge by Abejas and Coxcatlan phase customs). The deer bones show charring, cutting with stone (obsidian?) blades, and the occasional discarding of articulated hocks and lower limb fragments. The lack of dogs in this zone is interesting, in view of the fact that in village sites of the Santa Maria phase—as will be pointed out below—a larger proportion of dogs were eaten than during any other phase in the Tehuacan sequence.

Palo Blanco Phase

The archaeological levels attributable to this phase reflect mostly rainy-season camps of some duration. Trapping of small game was practiced, cottontails representing 21 percent of the animals recovered and skunks about 11 percent; foxes and gophers are also present. Some hunting of deer and peccary was done, with remains of the former constituting 18 percent of the total animals. Iguana and smaller lizards seem to have been collected, and a variety of wild birds included doves, songbirds, ravens, and others. At least one domestic turkey and four domestic dogs were eaten; this is the first evidence of the domestic turkey in the Tehuacan sequence. Remains of ameiva lizard and fetal deer place all of the cave occupations somewhere in the period between June and September.

Venta Salada Phase

Remains from these levels are similar to those from the Palo Blanco phase, with deer constituting only 14 percent of the total. Cottontails are only 14 percent of the individual animals represented, and fox, skunk, bobcat, opossum, and gopher are included in the smaller game. At least three dogs and two turkeys were eaten, and a number of wild birds were used for food. Iguana and ameiva lizards are also among the remains.

An interesting problem of seasonality is posed by Zone II, which had two sections. One was an occupation floor, and the other was tightly packed debris on which the floor rested. The sub-floor debris appears to have accumulated during the middle of the rainy season, since *Ameiva* and *Iguana* were present, but no remains of deer. The occupation floor is possibly attributable to the late rainy season or early fall; it contained remains of one deer and a fawn, as well as a gray fox whose first molar was just erupting. Foxes are born from March to May in southern Mexico (Alvarez del Toro 1952: 218), and the first molar would certainly have come through fully by late summer or early fall.

The Sequence in the Arroyo Lencho Diego, Subarea 4
(Purron Cave and Abejas Cave)

The Arroyo Lencho Diego is typical of the dry canyons in Subarea 4, whose natural resources have already been discussed. Two rock shelters located near the head of the canyon offered a long sequence of fauna from the area. The two caves are located close together, but in significantly different situations. Purron Cave (Te 272) lies in a blind canyon 50 to 60 meters deep, with no view except that of the opposite wall of the arroyo. Large game could not have been sighted from the cave, although small mammals could have been trapped in the area. Abejas Cave (Te 307), located just around the corner from Purron, has an excellent view of a small dissected alluvial apron on the slopes of the hills overlooking the main part of the Tilapa plain. From here, herds of deer or peccary could easily be seen as they moved through the area. The nearest surface water is a tiny trickle a kilometer away, on the other side of the ridge of hills which separates Abejas Cave from the main Tilapa plain. The topography is one of high rock cliffs, dry round-top hills, narrow canyons, and thorn-covered alluvial fans, at an elevation of 925 meters above sea level. Bone remains show that the fauna collected in the area by prehistoric man was limited to deer, cottontails, skunks, gophers, foxes, iguanas and other lizards, and quail and other small birds.

El Riego Phase

There are nine occupations in the arroyo from this period, but only four types of animals are involved. The totals (given in Table 17) suggest that deer and cottontails each constituted about 40 percent of the animals taken. Also present are birds and ameiva lizards, the latter indicating that at least two (and probably most) of the occupations were during the rainy season. As might be expected in this arid subarea, with little ground cover available, all but one of the rabbits are Audubon cottontails.

Numerous fragments of ribs, vertebrae, hooves, and such delicate cranial elements as the hyoid suggest that deer carcasses were brought intact to the cave and butchered there. The finding of calcanea, astragali, and distal ends of tibiae in articulation indicates that the hocks were discarded as a unit after being separated from the rest of the hind limb. Many of the long bones have been split open longitudinally so that marrow could be extracted. Countless bone splinters from these levels show the marks of heavy stone choppers. The

Table 17. Food Animals from the Arroyo Lencho Diego (Subarea 4) by Site and Phase

(Minimum Numbers of Individuals Derived from Identified Fragments)

	El Riego								Cox-catlan	Abejas						Purron		Ajal-pan	Santa Maria			Palo Blanco						
	Tc 307, H	Tc 272, S	Tc 272, R	Tc 307, G	Tc 307, F	Tc 307, E	Tc 307, D^2	Tc 307, D^1	Tc 272, Q	Tc 272, P	Tc 272, O	Tc 307, C	Tc 307, B	Tc 272, N	Tc 272, L	Tc 272, K	Tc 272, K^1	Tc 272, J	Tc 272, I	Tc 272, H	Tc 272, G	Tc 307, A	Tc 272, F	Tc 272, E	Tc 272, D	Tc 272, C	Tc 272, B	Totals
White-tailed Deer (indivs.)	1	1	2	1	1	1	1	1	1	2	1	1	1					1	1	1				1		1		20
antler			1																									1
teeth			6	1	1															1								9
ramus, mandible							1																					1
scapula				1					1																			2
humerus						1		1		2																		4
radius				1	1						2		1															5
innominate		1																										1
femur																		1	1					1		1		4
tibia				1	1	1				3	1							1	1									9
astragalus					1				1	2																		4
calcaneum			2		1					1																		4
metapodial	2		1	1	2		2		1			1	1						1	1						1		14
carpus tarsus	1												1															2
phalanx			1																	1								2
vertebra			1		1			1	1																			4
rib	1	1	5	2	2								1															12
other						1			1											1				1				4
Cottontails (indivs.)	1	1	1	2	1	1		2		1		1	1	1	1		1	1	2	6	4	1	2	2	1	1	1	36
maxilla						1												1		1	2							5
ramus, mandible		1												1			1		1	4	4			1				13
scapula				2	1					1										2	1	1	1	1	1			11
humerus																			3	4	1			2	1	1		12
radius	1				1										1				1	2								6
ulna															1					2								3
innominate			1	1				2						1					1	3	2						2	13
femur																			1	3	3			2	1			10
tibia			1									1	1		1					3	1		2		1			11
metapodial			1											2										2		1		6
other														1				1		2	1				1		1	7
Dog (indivs.)															1			1		1			1					4
teeth															1					2								3
ramus, mandible																				1			1					2
radius																				1								1
vertebra																		2		1			2					5
rib																		1		2								3
Skunk (indivs.)																1								1				2
fragments																2								1				3
Gopher (indivs.)																				1								1
fragments																				1								1
Fox (indivs.)																								1		1		2
fragments																								9		3		12
Iguana (indivs.)																					1			1				2
fragments																					2			3				5
Other Lizards (indivs.)			1	1					1																	1		4
fragments			4	1					1																	2		8
Quail (indivs.)																				1								1
fragments																				2								2
Other Birds (indivs.)			1					1						1		1			1				1			1		7
fragments			2					1						1		1			1				1			2		9

deer involved are of all age groups, from fawns and yearlings to adult does and four-point bucks, showing a random sample of the local population of white-tails.

Numerous as fragments of deer are, in only one case is there evidence that more than a single individual was present in a given zone. In all but two cases, this is true of the cottontails as well. Our impression, therefore, is that occupations in the Arroyo Lencho Diego during the El Riego phase were mostly rainy season camps of brief duration, during which little effort was made to exploit the small game of the area beyond trapping a few cottontails. The band probably moved on as soon as they killed whatever deer or other large game happened to be in the vicinity.

Coxcatlan Phase

Hunters camped only once in the Arroyo Lencho Diego during this phase; they killed a single deer and then moved on. Remains of ameiva lizard suggest that the camp was made during the rainy season.

Abejas Phase

Six zones in Purron and Abejas caves date to this period, and all show significant contrasts with the El Riego and Coxcatlan phase levels in the same caves. First of all, there is a complete lack of ameiva lizards or other rainy-season indicators, and a virtual absence of small game except for cottontails. The five deer killed during this phase are represented almost exclusively by long-bone fragments; skull elements, hooves, and all bones below the metapodial are completely lacking, as are vertebrae. Thus, these animals may have been butchered at the site of the kill and selected parts brought to the cave from some distance away. Long bones were split for marrow, and hocks were discarded with all three components still articulated. Our suspicion, although based on admittedly slim evidence, is that these six occupations are brief dry-season camps by wide-ranging microbands, during the time of year when wild resources were at their lowest ebb.

In Zone L of Purron Cave (about 2500 B.C.) appears the first evidence for domestic dog in Subarea 4. The evidence (a single tooth) is painfully slim, but is supported by the finding of dog remains from Abejas levels in Coxcatlan Cave, as pointed out above.

Purron Phase

Two brief occupations, Zones K[1] and K in Purron Cave, produced a single Audubon cottontail, one spotted skunk, and a small bird.

Ajalpan Phase

Zone J of Purron Cave contained the remains of a deer, a domestic dog, and one Mexican cottontail.

Santa Maria Phase

This is the first phase in the subarea to produce evidence of occupations of some duration. For the first time there is evidence of significant amounts of trapping of the locally available small game, including twelve cottontails, as well as gopher, black iguana, quail, and an unidentified small bird. Also present were the remains of dog and white-tailed deer. Both the dog and cottontail remains show signs of roasting, and the deer bones are split lengthwise for extracting marrow.

The dog remains from Zone H of Purron Cave included a complete right mandible, 103 mm. long, with six cheek teeth intact. The specimen has no first premolar (lacking even the alveolus), but this may be a genetic defect of this particular individual. Dogs from Santa Maria levels in other subareas do not lack the first premolar.

Palo Blanco Phase

Six occupations make this one of the best-represented periods in the prehistory of the Arroyo Lencho Diego. The pattern of hunting has more similarities to the Santa Maria phase than to any of the preceramic periods. Cottontails represent about 45 percent of the individual animals present, and there is evidence for trapping of fox, striped skunk, black iguana and other lizards, and a few small birds. Also eaten were white-tailed deer and domestic dogs. Remains of ameiva lizard indicate that Zone C of Purron Cave was a rainy-season occupation. The other zones from this period lack *Ameiva* remains, but they are so similar in other characteristics that we suspect they too may be rainy-season occupations of the same type. Both of the deer involved are immature.

Occupations during the Palo Blanco phase, like those during the Santa Maria period, do not seem to have been particularly brief, but there is no evidence of intensive hunting. Whatever their reasons for being in the Arroyo Lencho Diego, obtaining meat was not the primary purpose of these campers, and bone remains reflect mainly their trapping of small game, probably incidental to their other rainy-season activities. The latter may have included the harvesting of crops irrigated by water held by the large dam that was built in the area.

Table 18. Food Animals from Tecorral Canyon (Subarea 2) by Site and Phase
(Minimum Numbers of Individuals Derived from Identified Fragments)

	El Riego and Ajuereado	Coxcatlan		Abejas	Ajalpan	Palo Blanco			Venta Salada	
	Tc 255, C	Tc 254, F	Tc 254, E	Tc 254, D	Tc 254, C'	Tc 254, C	Tc 254, B	Tc 255, B	Tc 255, A	Totals,
Antelope (indivs.)	1									1
fragments	2									2
White-tailed Deer (indivs.)			1				1	1		3
fragments			1				6	1		8
Peccary (indivs.)			1				1		1	3
fragments			1				3		1	5
Cottontails (indivs.)	2	1	3	3	1	1	4	2	2	19
maxilla			1	1			2			4
ramus	2	1	2	1	1		3	1		11
scapula			3	1			2			6
humerus			2	3			3	2	2	12
radius				1						1
ulna			1	1			2		1	5
innominate	1	1		3		1	3			9
femur	1		2	4						7
tibia	1	1	1	2			3			8
metapodial							2			2
vertebra			4	4		1	10	1		20
other	1		8				6			15
Coyote (indivs.)	1	1								2
fragments	1	1								2
Dog (indivs.)							1			1
fragments							3			3
Fox (indivs.)	1					1				2
fragments	2					1				3
Gopher (indivs.)		1	1				1	2	1	6
fragments		1	1				4	2	3	11
Skunk (indivs.)				1					2	3
fragments				1					2	3
Extinct Turtle (indivs.)	1									1
fragments	2									2
Other Turtles (indivs.)		1	1	1			1			4
fragments		3	3	3			5			14
Lizard (indivs.)	1		1	1			1			4
fragments	1		7	2			2			12
Snake (indivs.)							1			1
fragments							2			2
Quail (indivs.)		1								1
fragments		1								1
Dove (indivs.)				1						1
fragments				1						1
Song-birds (indivs.)							2		1	3
fragments							2		5	7
Other Birds (indivs.)							1		1	2
fragments							3		1	4

This is the last period for which we have evidence of cave occupation in the arroyo.

The Sequence in Tecorral Canyon, Subarea 2
(San Marcos Cave and Tecorral Cave)

The ecology of Subarea 2 and the specialized canyon niches within it has already been discussed. Both Tecorral Cave (Tc 255) and San Marcos Cave (Tc 254) are shallow rock shelters overlooking the alluvial bottom of a deep travertine canyon at an elevation of 1550 meters above sea level and have access to the fauna of both the brushy canyon floor and the barren rock cliffs and slopes above it. Archaeological remains show that during the nine or ten thousand years when these rock shelters were sporadically occupied, the animals most commonly eaten in the area were deer, peccary, cottontails, coyotes, foxes, gophers, striped and spotted skunks, turtles, lizards, snakes, and several types of bird, including dove and quail. Actually, Tecorral Canyon is a fairly poor hunting locality, and the bone remains reflect this (see Table 18). Small game which could be obtained by trapping is quite varied, but larger mammals like deer and peccary which would have been obtained by hunting are poorly represented. In fact the whole aspect of Tecorral Canyon is one of an area where man may have camped temporarily to plant or harvest corn or collect wild plants, and only incidentally did a little trapping.

Zone C of Tecorral Cave

This level is unfortunately mixed, making it impossible to assign the bones to a given culture. Many of the diagnostic artifacts from Zone C are characteristic of the El Riego phase (6500 to 4900 B.C.). A number of the bone fragments, however, belong to animals which were presumably already extinct in the Tehuacan Valley before the start of this phase. The matrix of this shallow level was yellow rock dust in which no sublevels could be discerned, and it was only during analysis in the laboratory that the mixed nature of the deposits became apparent. Perhaps the situation was one in which a very shallow Early Ajuereado occupation with very few artifacts was closely overlain by a brief El Riego occupation and possibly even further intermixed by intrusive pits. We are left, thus, with the following situation: Squares W2 and S1W2 of this zone contain two scutes of large "extinct" turtle and the cheek tooth of an antelope; Squares S2E1 and S1E2 contained the remains of an ameiva lizard and a Mexican cottontail. Faunally, Zone C is not very helpful except to indicate that the rock shelters in Tecorral Canyon were visited by man before 7000 B.C.,

and that during the El Riego phase (when the climate had become roughly what it is today) they were occasionally used as rainy-season campsites.

Coxcatlan Phase

Zone F of San Marcos Cave produced cottontail, gopher, and quail, as well as fragments of coyote and mud turtle. The presence of the latter suggests that there was water flowing in Tecorral Canyon at the time; whether this was seasonal or perennial is unknown. Zone E, branded as a rainy-season occupation through the presence of bones of ameiva lizard, shows the remains of deer and peccary, cottontails and gophers. Once again, fragments of turtle are present. The seasonal information correlates well with the presence of primitive "improved" corn in this level, which indicates that Tecorral Canyon was being occupied briefly during the late rainy season when corn was ready to harvest.

Abejas Phase

Zone D of San Marcos Cave, a rainy season occupation, was probably also a temporary camp during the period of the corn harvest. Present are the remains of three cottontails, a spotted skunk, turtle, ameiva lizard, and white-winged dove.

Ajalpan Phase

The only bone present in Zone C of San Marcos Cave is the mandible of an Audubon cottontail.

Palo Blanco Phase

This includes three brief occupations, two in San Marcos Cave and one in Tecorral Cave, at least one of which (San Marcos, Zone B) can be traced to the rainy season. The totals for all three zones show seven cottontails, two deer, a peccary, a fox, three gophers, turtle, lizard, snake, one domestic dog, and three birds. The skull and hoof fragments present suggest that carcasses of both deer and peccary were being brought intact to the cave and butchered there.

Venta Salada Phase

Zone A of Tecorral Cave showed the remains of two cottontails, a peccary, gopher, hooded skunk, spotted skunk, and two birds.

The Sequence at El Riego Springs, Junction Between Subareas 1 and 2

(El Riego Cave, East and West Niches)

El Riego Cave is an excellent location for a hunting site, since it lies almost at valley level (1650 meters) with its West Niche facing east over the Tehuacan plain. The slight elevation of the cave is just sufficient to afford it an unobstructed view of game moving through the area for half a kilometer in three directions. There are many springs along the base of the cliff, and more surface water than in most of the Tehuacan Valley.

The ecology of the area has already been discussed. The cave is in a specialized habitat located at the boundary between the long, level alluvial plain near the city of Tehuacan and the barren travertine cliffs behind it, which are part of Subarea 2. Campers in the cave could draw on the fauna of both subareas, as well as animals that came to the springs for water. Animals eaten in the area included deer, peccary, cottontails and jack rabbits, gophers, opossums, foxes, skunks, rock squirrels, snakes and lizards, turtles, doves, hawks, and other birds.

Late Ajuereado Phase

A very brief occupation in Zone 6, West Niche of El Riego Cave, shows only the remains of Mexican and Audubon cottontails.

El Riego Phase

Zone 5 of the West Niche, also a very brief occupation, contained only the bones of one white-tailed deer and one cottontail rabbit.

Coxcatlan Phase

Zone 4 of the West Niche suggests that a brief camp was made during this phase. Two cottontails were trapped and one deer eaten, along with a jack rabbit, a gopher and one dove. Some long bones of deer appear to have been cut on both ends with a flint blade, into sections which could have been used as tubes or beads.

Palo Blanco Phase

Two camps made in the East Niche of the cave during this phase support the contrast (seen in earlier levels at other caves) between rainy-season and dry-season activities. Zone E, a dry-season camp which involved the butchering of a deer with fully hardened antlers, had little small game. Zone D, a rainy-season camp, was rich in small fauna, including six cottontails, three opossums, and other forms like gopher, jack rabbit, bird, and snake. The suggestion is that rainy-season camps were mostly for wild-plant collecting and small-game trapping, with proportionally more hunting of deer in the dry season.

Signs of rodent gnawing on bones from Zone D (East Niche) show that the bones lay on the surface for some

time after the deposition of this layer. Sometime between the abandonment of Zone D and the deposition of Zone C, a barn owl inhabited El Riego Cave and left a large clutch of owl pellets, which were later uncovered by the excavators, all in a single one-meter square. The abundant small rodent remains from these pellets have not been included in the tables of animals eaten by occupants of the prehistoric sites, but are listed above in the discussion of owl diet.

Venta Salada Phase

Six zones in El Riego Cave date to this period; half of these showed evidence of camps made at intervals throughout all seasons of the year. Cottontails constituted 33 percent of all the individual animals eaten at the cave, and domestic animals (dog and turkey) about 17 percent. Deer and peccary together constituted only 15 percent of the individual animals, with the remainder made up of small species like gopher, opossum, jack rabbit, fox, skunk, rock squirrel, turtle, and lizard.

In these levels there is considerable evidence of the butchering technique practiced during the Venta Salada phase. Deer are of all age groups from yearling to three-year-old, and the variety of bones suggests that the carcasses were brought to the cave intact. There the head was separated from the trunk by a cleaver blow, dividing the atlas from the axis. The antlers were torn from the skull, and some were cut into sections for use as antler hammers. The deer were roasted, and some of the bones must later have been kicked into the fire, for they are calcined almost white. Dogs were also roasted and the skull broken open for removal of brains. Long strings of vertebrae from these animals are completely charred, as if the dogs had been roasted over hot coals. Cottontails, gophers, and opossums also show charring of this type. Clusters of preserved turkey feathers show that these animals were plucked in the cave, and bones from their limbs and trunk show that they, too, were roasted. Charred skulls of two ameiva lizards and the partial skull of another suggest that these animals were roasted and eaten, all but the snout. The skulls are all clipped off right at the occipital region, and with one exception the limb bones are completely gone, suggesting that the whole animal was crunched up in the mouth of the person eating it.

Not all the animals found in Venta Salada levels were eaten, however. In Zone 3 of the West Niche were found the complete, articulated skeletons of two buried dogs, puppies which on the basis of the teeth should have been two or three months old. Since these animals were obviously not eaten, they were not included in the food counts from Zone 3 shown in Table 16. Whether they represent an offering or simply a prosaic burial of two dead puppies is a problem beyond the scope of this paper. In Zone A of the East Niche we found the completely mummified corpse of a striped skunk (*Mephitis macroura*) which had obviously burrowed into the cave and died. Everything but the odor had been preserved.

The Sequence from the Ajalpan Plain, Subarea 1 (Ajalpan, Coatepec, Las Canoas, and Quachilco)

Our picture of prehistoric hunting patterns in this part of Subarea 1 comes from the four village sites of Ajalpan (Ts 204), Coatepec (Ts 368), Las Canoas (Ts 367), and Quachilco (Tr 218). The first three sites are located within a kilometer or so of each other near the east bank of the Rio Salado, just south of the present village of Ajalpan. Quachilco lies five kilometers to the southwest. Approximate altitude of the level plain is 1230 meters. The resources both of the alluvial plain surrounding the sites and of the arroyo of the Rio Salado, a specialized niche within Subarea 1, are available to all four locations.

The natural resources of Subarea 1 have already been discussed. Archaeological remains tell us that the wild animals selected as staple foods by the villagers in this subarea were white-tailed deer, peccary, cottontails, gophers, and mud turtles. Domestic dogs also constituted a large percentage of their food supply. Also hunted, but in lesser frequency, were jack rabbits, coyotes, raccoons, striped skunks, lizards, quail, hawks, possibly ravens, and even an occasional mountain lion. With the exception of the latter species, most of these animals would have been found in the vicinity of the village or in the riverbank thickets.

Ajalpan Phase

The Ajalpan phase is distinguished from later periods in the area by more intensive dry-season deer hunting, greater use of turtles from the Rio Salado, and relatively lower proportions of small animals such as cottontail. Totals from the phase (see Table 20) show that deer represented 50 percent of the animals eaten, domestic dogs about 17 percent, turtles about 11 percent, and cottontails only about 8 percent, with peccary, coyote, lizards, and birds making up the remainder. Deer bones from middens dating to this phase are frequently roasted or charred and sometimes show the marks of stone blades. Many of the bones look as though they had been made into blanks for bone tools. In Zone G of the Ajalpan site we have evidence that the common deer-metapodial awls of this period were

Table 19. Food Animals from East and West Niches of El Riego Cave by Zone and Phase

(*Minimum Numbers of Individuals Derived from Identified Fragments*)

	Late Ajuer-eado	El Riego	Cox-catlan	Palo Blanco		Venta Salada						
	Tc 35w, 6	Tc 35w, 5	Tc 35w, 4	Tc 35e, E	Tc 35e, D	Tc 35e, C	Tc 35e, B	Tc 35w, 3	Tc 35w, 2	Tc 35w, 1	Tc 35e, A	Totals
White-tailed Deer (indivs.)		1	1	1	2	2	2	1		1	1	12
antler				1		2	2				1	6
teeth					1	3		1				5
ramus				1		1	1					3
scapula				1								1
humerus				1							1	2
radius				1	2			1				4
ulna					2		1				1	4
innominate					1							1
femur					1			1				2
tibia		1								1		2
astragalus							2			1		3
calcaneum											1	1
metapodial			1		2			1		1		5
phalanx			1	1	2	7	3	2			4	20
vertebra			1	1	2		1				1	6
rib					2	1					1	4
other			1	1	1	1	1	2				7
Peccary (indivs.)					1	1	2				1	5
maxilla					1	1						2
mandible							1					1
teeth					1							1
femur						1						1
tibia							1					1
metapodial							3					3
phalanx											1	1
other					6	2	4				1	13
Cottontails (indivs.)	2	1	2	2	6	8	3	2	2	1	9	38
maxilla				1	3		1					5
ramus		2			7	7	3	3			4	26
scapula			1		3	2	1	1			1	9
humerus					2	1	1	2		2	2	10
radius		1				1		1				3
ulna			1								1	2
innominate	2	1		1	3	5	3	1	2		3	21
femur			2		3	1	4	2	1		2	15
tibia		1		1	2	5	1	1			5	16
metapodial					2			1			5	8
phalanx											4	4
vertebra							1			3	1	5
other				1			2	1			3	7
Domestic Dog (indivs.)				1	2	2	1	1			1	8
ramus						3	1					4
scapula					1							1
humerus					2							2
radius					2							2
Domestic Dog (cont.)												
ulna				1	2	1						4
innominate					1							1
femur					2							2
tibia					1	1					1	3
calcaneum				1		1						2
astragalus								1				1
metapodial					8	6		1				15
phalanx					1							1
vertebra				2	2	10		8				22
other					1	2					2	5
Turkey (indivs.)						3	1	1		1	2	8
beak								1		1		2
humerus						1						1
coracoid							1			1		2
radius						1						1
carpometacarpus							1				2	3
femur										1		1
tibia						3				1	2	6
tarsometatarsus								1			1	2
other						10	3				2	15
Jackrabbit (indivs.)			1		1			1	1			4
fragments			2		1			1	1			5
Gopher (indivs.)			1		1	3		3		1	2	11
fragments			1		3	5		6		1	4	20
Opossum (indivs.)				1	3	1				1	1	7
fragments				3	15	4				3	6	31
Fox (indivs.)								1				1
fragments								1				1
Skunk (indivs.)										1		1
fragments										1		1
Rock Squirrel (indivs.)											1	1
fragments											4	4
Lizard (indivs.)						3	1	1			1	6
fragments						6	1	3			5	15
Snake (indivs.)					1							1
fragments					1							1
Turtle (indivs.)						1					1	2
fragments						1					1	2
Dove (indivs.)			1									1
fragments			1									1
Hawk (indivs.)				1								1
fragments				4								4
Other Birds (indivs.)					1						1	2
fragments					1						2	3

Table 20. Food Animals from the Ajalpan Plain (Subarea 1) by Site and Phase (Minimum Numbers of Individuals Derived from Identified Fragments)

	Ajalpan										Santa Maria																									Palo Blanco		Venta Salada			
	Ts 204, H	Ts 204, G	Ts 204, G^1	Ts 204, F	Ts 204, F^1	Ts 204, E	Ts 368, K^3	Ts 368, K^2	Ts 368, K^1	Ts 368, J	Ts 368, I	Ts 368, H	Ts 368, G	Ts 368, F	Ts 368, E	Ts 367, D^2	Ts 367, D^1	Ts 367, C	Ts 368, D	Ts 368, C^2	Ts 368, C^1	Ts 368, C	Ts 368, B	Ts 204, C-D	Ts 204, B	Ts 204, A	Tr 218-10, C^2	Tr 218-6, F	Tr 218-10, C^1	Tr 218-10, C	Tr 218-10, B^1	Tr 218-10, B	Tr 218-6, D	Tr 218-6, C	Tr 218-6, B	Tr 218-10, A	Tr 218-6, A	Ts 367, B	Ts 367, A	Ts 368, A	Totals
White-tailed Deer (indivs.)	3	5	4	3	2	2	2	3	1	1	3	1	1	2	1	1	1	1	2		1		1	1	1	1	1	1	1	1	1	1	1		1			1		1	54
antler	1	4	1		2		1				1	1	1	1	1									1	1		1		1												18
teeth		2																												1											3
ramus, mandible	1	1	1	1	1	1		1						1																1											9
scapula	1	5	5	5	2			3			3			2			1	1																							28
humerus	3	3	2	5	2			2	1	1		1		2	2	1															1		1							1	28
radius	2	3	2	4	2			2				1		1	2				2				1	1		1					1				1			1		1	28
ulna	2	5	1	3	1	2	1			1	2	1		2	1										1																23
innominate	3	2	3	2				1	1		2		1	1	1			1	1		1																			1	21
femur	2	6	2	3					1																1																15
tibia		5	1	1	1			2																																1	11
calcaneum	3	1	1	1							1		1																												8
astragalus		3	2	1	2	1		1						1																											11
metapodial	1	4	2	2		1	2			2	1		1	3			2	1												1	1		1		1			1		1	28
carpus/tarsus		1	1								1																														3
phalanx	4	5	2	4		4		1	1		1	1		1	1						1		2			1		1			1	2								2	35
vertebra	19	11	12	8		2	2	2			3		1	2				2	3				1	1			2	1													72
rib	1	3		7	2	2	1					1		1									1							1	3									1	24
other	6	3	2	3						1					1	1					1																				18
Peccary (indivs.)	1	1	1	1									1		1									1																	7
tooth	1			1																																					2
ramus, mandible			1	2											1																										4
maxilla	2		1																																						3
scapula	1		1	1																				1																	4
humerus																								1																	1
radius		1																																							1
ulna		1																																							1
femur				1																				1																	2
tibia		1																																							1
metapodial													1																												1
phalanx															1																										1
other	4												1																												5
Domestic Dog (indivs.)	2	2	1	1	1		1	1			1	1	1	2	2	2	2	2	1		1	1	2				1		1	1	1		1	1	3	1	1	1	1	1	41
teeth	1	4									1	1		5	2	1	3	3			1								2						1			1	1		27
ramus, mandible		2	1		1							2	1	2	1	1	1	2				1	1				1		1	1					3		1				23
cervicals	1	1	1															1				1											2							1	8
humerus		1		1	1			1						1		1					1													1							8
radius															1	1		1																					1		4
ulna											1					1																		1						1	4
innominate					1								1	1	2								1											1				1			8
femur				1																																1					2
tibia		1														4	3	1															1								10
calcaneum														1			1	1																							3
astragalus														1																											1
metapodial															3		3	4	4	1											1	1			1				1		19
phalanx															1				2	1			1	2																	7
other			2					1					1		3									1																	8

	Ajalpan										Santa Maria																									Palo Blanco		Venta Salada			
	Ts 204, H	Ts 204, G	Ts 204, G^1	Ts 204, F	Ts 204, F^1	Ts 204, E	Ts 368, K^3	Ts 368, K^2	Ts 368, K^1	Ts 368, J	Ts 368, I	Ts 368, H	Ts 368, G	Ts 368, F	Ts 368, E	Ts 367, D^2	Ts 367, D^1	Ts 367, C	Ts 368, D	Ts 368, C^2	Ts 368, C^1	Ts 368, C	Ts 368, B	Ts 204, C-D	Ts 204, B	Ts 204, A	Tr 218-10, C^2	Tr 218-6, F	Tr 218-10, C^1	Tr 218-10, C	Tr 218-10, B^1	Tr 218-10, B	Tr 218-6, D	Tr 218-6, C	Tr 218-6, B	Tr 218-10, A	Tr 218-6, A	Ts 367, B	Ts 367, A	Ts 368, A	Totals
[Table 20 cont.]																																									
Cottontails (indivs.)		1		3							1	1	1	2	1		1	2	1		1		2		1				1	2	2	2			1	1		1		2	30
maxilla				3																																					3
ramus													1	1									2						1	1	1	1									8
scapula																																				1					1
humerus																		1			1		2								1				1					1	7
radius																																1									1
innominate				1									1	3	1			2					1							1		2									12
femur												1		1											1				1	1		1			1	1				2	10
tibia		1									1			1					1				1								1				1			1		1	9
other																	1	3					1								2	1								1	9
Jackrabbit (indivs.)															1		1	1	1	2	1	1	1					1			1										11
ramus																											1														1
scapula																											2				1										3
humerus															1			1																							2
innominate																	1		1		1		1					1			1										6
femur																					1	1									1										3
tibia																					1	1																			2
other																			1			3																			4
Gopher (indivs.)											1			1		1		1	1										1	1	2		1	1	2						13
ramus														1																	2			1	2						6
tooth																1		1											1												3
humerus											1																														1
femur																														1			1								2
tibia																			1																						1
other																															2										2
Coyote (indivs.)	1																																								1
fragments	3																																								3
Puma (indivs.)																	1																								1
fragments																	2																								2
Raccoon (indivs.)												1			1																								1		3
fragments												1			1																								1		3
Skunk (indivs.)																														1											1
fragments																														2											2
Turtle (indivs.)	1	1	1	1				1	1														1																		7
fragments	1	1	13	5				1	2														1																		24
Lizard (indivs.)		1																																							1
fragments		2																																							2
Raven? (indivs.)		1																													1										2
fragments		2																													1										3
Quail (indivs.)																					1	1	1											1							4
fragments																					1	2	1											1							5
Hawk (indivs.)																											1														1
fragments																											1														1
Turkey (indivs.)																																								1	1
fragments																																								1	1

manufactured while the bone was still fresh from the butchering process; one metapodial awl from a very young deer showed the shaft and unfused articular end still connected, as they would have been while the sinew was still holding them together.

The lowest five zones of the Ajalpan site (Ts 204) show an interesting pattern of seasonal occupations. Zones F[1], G[1], and H, all of which are living floors, all have evidence of dry-season occupation. Lying on each of these floors were completely hardened antlers, in the state in which they are normally found between October and February, broken off the skull in such a way that fragments of frontal bone are still clinging to them. None of the ameiva lizards so common in the rainy season are present in these levels. Zone G, which is a layer of refuse under floor G[1], has evidence of year-round occupation. The stump of an antler which appears to have been in velvet at the time the deer was killed, plus fragments of ameiva lizard, indicate a summer occupation; other fragments of hardened antler suggest deer which were killed during the dry season. Occupation at the village of Ajalpan was certainly year-round, though we are not yet sure why living floors all appear to date to the dry season.

Santa Maria Phase

Twenty-five components of the Santa Maria phase in Subarea 1 yielded identifiable animal bones; a minimum of 113 individual animals were recovered. Dog, deer, and cottontail represented nearly three-quarters of the total, and the rest of the animals were mostly large pocket gophers and jack rabbits.

When compared with the Ajalpan phase levels in the same subarea, the Santa Maria phase shows an increase in consumption of dog; that animal constituted about 24 percent of the individual animals. Deer had dropped to about 23 percent, and cottontails had risen to 19 percent. Mud turtles seem to have been less popular, with only one fragment recovered. Rare animals included peccary, striped skunk, raccoon, quail, raven, and hawk. A single mountain lion appeared in Zone D[1] at Las Canoas.

With increased use of domestic animal food, and a decrease in hunting, the Santa Maria phase also showed more wasteful butchering techniques than the previous phases. Far fewer bones were split longitudinally for marrow, and numbers of deer limb bones were discarded while still in articulation. Repeated cutting with flint or obsidian blades is obvious on a number of deer bones, in areas where tendons had to be cut in order to free the muscle from the bone. During the occupation of Zone G at the site of Coatepec it was the custom to remove the head of the femur from the acetabulum of the pelvis in this manner, and cut marks are present on several acetabula. Villagers made awls from deer metapodials, and numerous rejected tool attempts or "blanks" were found in the debris. The canine teeth of the mountain lion killed at Las Canoas had been removed and polished as ornaments.

Palo Blanco Phase

The two components of this phase showed only the remains of dog and cottontail. One unidentifiable fragment of long bone from Zone A, Test 10, at Quachilco had been slotted, as if by a burin or the edge of a blade. Also included in the rubbish were blanks for bone beads. These were long shaft fragments separated into a series of shorter tubes by means of deep grooves cut part-way through with a flint or obsidian blade, but never finished.

Venta Salada Phase

Venta Salada deposits exposed in Subarea 1 are few, and the scarcity of bone fragments does not allow us to draw many conclusions. Most commonly eaten were dogs (30 percent), cottontails (30 percent), and deer (20 percent). Traces of raccoon and turkey were also present.

Animals Present but not Eaten

The large numbers of small rodents found in the Tehuacan caves have already been discussed. For a number of reasons, we do not believe that many of those small rodents—wood rats, cotton rats, kangaroo rats, and others—represent animals eaten by prehistoric residents of the valley. First of all, most of them had clearly been deposited in the caves in owl pellets. Still others, especially in the upper levels, were mummified individuals who had obviously crawled inside and died. None were burned. Most skulls were still intact, a condition which could never have obtained had the small rodent crania been lying on the surface at a time when men were walking back and forth in the cave. Hence the small rodents have been used mostly as climate indicators (Table 15) and are not included in the food remains.

This does not mean that small rodents were never part of the human diet at Tehuacan; in fact, Eric Callen's coprolite analysis (Chapter 13) suggests that kangaroo rats and other small wild mice occasionally were eaten by the prehistoric occupants of the Tehuacan caves. Probably, as indicated by bone and hair fragments in the coprolites, these small rodents were eaten whole; hence almost nothing would have re-

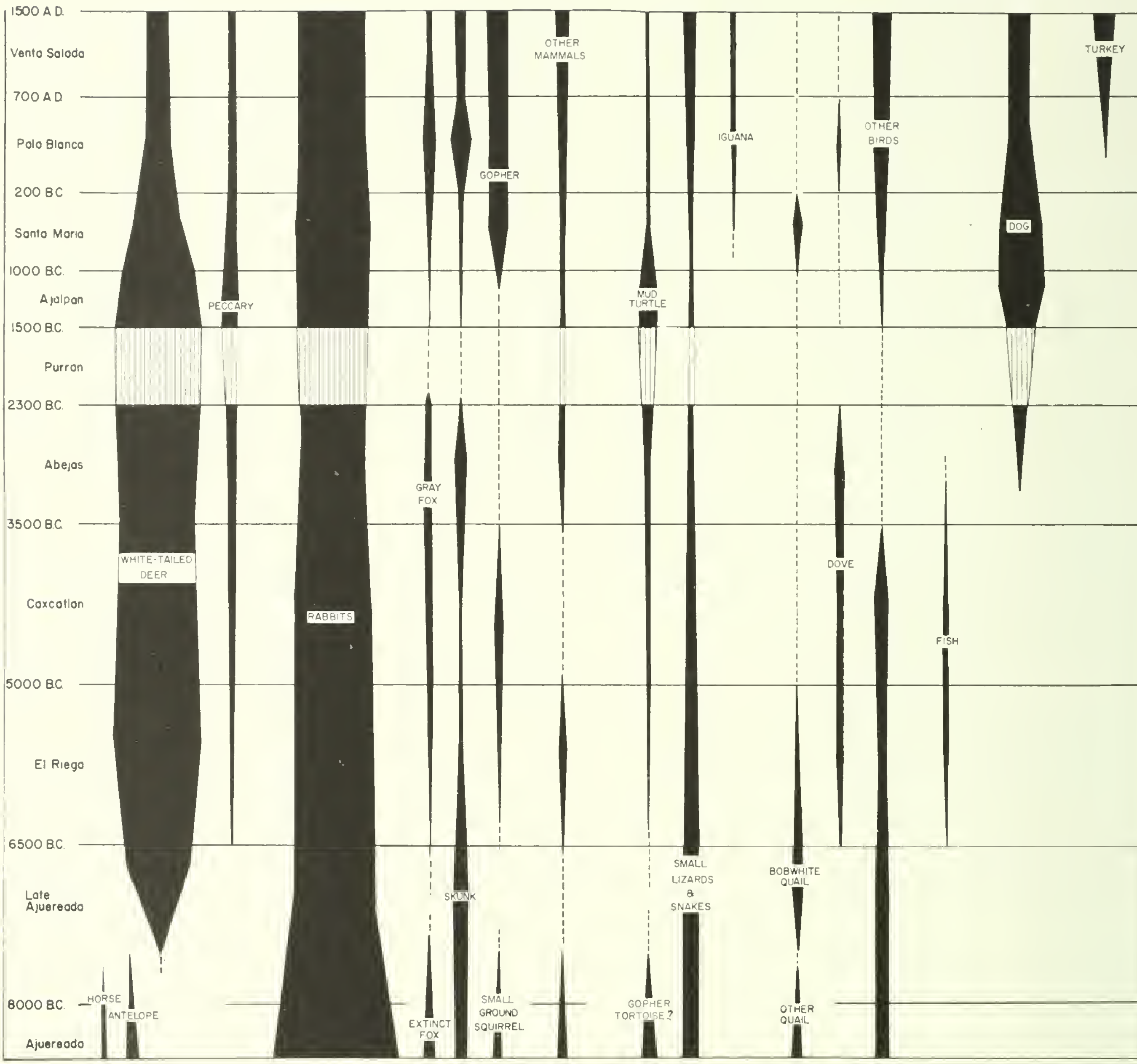

Fig. 95. Exploitation of the fauna by inhabitants of the Tehuacan Valley.

mained for the osteologist to identify. The rodents I examined had either been eaten by owls, or seem to have died a natural death in their burrows in the cave.

Other animals which obviously did not serve as sources of food for the human inhabitants include the remains of at least four bats of unidentified species (Tc 50, Zones XXVIII, XV, III, II); one fruit bat (Tc 50, VI) and one brown bat (Tc 50, II); two murine opossums (Tc 50, II, and Tc 35e, owl pellets between Zones C and D); two juvenile cottontails, a juvenile gopher, and a small bird from owl pellets (Tc 35e, C–D); one black iguana (Tc 272, A); one mummified striped skunk (Tc 35e, A); and the skeletons of two puppies (Tc 35w, 3). Intrusive fragments of modern sheep and goats were found in the uppermost layers of Purron and San Marcos caves.

Pre-Columbian Hunting Patterns

What follows is a brief summary of the data from all subareas, relating to the way hunting patterns in the Tehuacan Valley changed through time. The reconstructions are based on the concrete data given above, but we have been quite free in the interpretation of that data. Let us first state our basic premises with regard to prehistoric hunting technique:

1. We infer from the large numbers of spear, atlatl, and arrow points recovered by the Tehuacan Project that large mammals like deer and peccary were obtained by hunting.

2. We infer from large numbers of trap fragments (whittled sticks, some with slip knots of maguey fiber attached, etc.) recovered in the same levels that small animals, especially the primarily nocturnal ones like skunk and cottontail, were trapped or snared. This may also apply to birds like quail. Gophers are widely trapped in Mexico today by means of deadfalls, and in the Valley of Mexico, Villa (1953: 379) states that some professional gopher-catchers or "tuzeros" average ten animals a day.

3. We suspect that animals with a sharply delimited habitat and fairly predictable habits, like the mud turtles in the Rio Salado, were virtually "collected."

4. Small, abundant animals of little nutritive value, like ameiva lizards, were probably casually collected around campsites with no more expenditure of effort than is necessary to throw a rock.

Fig. 95 shows frequency polygons of the percentage of the recovered fauna which certain categories of animals represented during various parts of the Tehuacan sequence. These frequencies are based on the number of individual animals present, and not on the number of pounds of meat represented by each species. We approve of White's system (1953), but had we done our graph on the basis of pounds of usable meat, the deer column in every period would have shoved all others to one side of the page, obscuring some of the subtler changes in small game trapping we wished to bring out. Our chart is not of meat, but of human activities, since we feel that the trapping of ten or fifteen rabbits and a skunk or two is an expenditure of energy worth bringing to light, even if the number of pounds of meat involved does not total as much as the meat from a single deer. Fig. 95, therefore, should be taken as an indication of the different ways in which pre-Columbian man was spending his time in pursuit of meat during a given phase in the prehistory of the Tehuacan Valley.

Early Ajuereado Phase (before 7000 B.C.*)*

This phase took place when some of the Pleistocene fauna was still lingering on in the Tehuacan Valley, but bone remains clearly show that man was not the "big-game hunter" he is often made out to be during this period. The hunting and/or trapping of rabbits produced 55 percent of the individual animals found in this phase, and other small game, such as fox, skunk, coyote, ground squirrel, turtle, and lizard, were also important. The numbers of extinct horses and antelope are relatively small. Remains of mammoth have been found underneath the city of Tehuacan and examined by Arturo Romano of the Instituto Nacional de Antropología e Historia (MacNeish, personal communication), and it is possible that even they were hunted during this period, though not, of course, carried back to the caves and rock shelters.

In this respect, our Early Ajuereado faunal remains correlated well with Alexander's data from early levels at the Levi Rock shelter in Texas (Alexander 1963: Table 1), where Lundelius has identified, beside the usual big game (bison, deer, antelope, horse, tapir, and an extinct peccary), numerous smaller animals such as skunk, wolf, coyote, bobcat, raccoon, cottontail, jack rabbit, gopher, mole, wood rat, cotton rat, and others, as well as fish, snails, and large quantities of mussels (*ibid.*:513). We suspect that big-game "kill sites" during the Early Ajuereado phase (and such must certainly exist somewhere in the Tehuacan Valley) probably looked no different from Santa Isabel Iztapan (Aveleyra 1955). The campsites and rock shelters, however, give a fuller and very different picture of the economy of the time.

If Julian Steward's views on "cultural regularities" among primitive people in ecologically similar areas are valid (Steward 1955), we should be able to discern some parallels between the Early Ajuereado hunters and other nonagricultural Indian groups sharing an antelope–jack rabbit desert environment. Perhaps the most applicable example given by Steward himself is the Great Basin Shoshone, whom he knew particularly well. They, too, lived in a region of intermontane steppes and desert with low xerophytic scrub where "the two species of greatest importance to the Indians were antelope and rabbits . . . the Shoshoneans probably ate more rats, mice, gophers . . . snakes, and lizards than large game" (*ibid.*:104). This correlates well with our impressions of Early Ajuereado subsistence, and suggests that even the wood rats (*Neotoma*) and deer mice (*Peromyscus*) found in Zones XXV–XXVIII of

Coxcatlan Cave may have been eaten (see Table 15).

When game was sufficiently abundant, the Shoshone held collective hunts, of which the most common was the rabbit drive. Men, women, and children beat the brush over a wide area, either driving the rabbits ahead of them into nets or enclosures or else clubbing and shooting them along the way (*ibid.*:109). Frankly, without attempting to claim that similar specific techniques were used, I find it hard to explain the disproportionately large numbers of rabbits in Early Ajuereado levels—forty in Zone XXVI alone—without recourse to communal drives of this kind. Communal antelope drives were also held by the Shoshone, but less frequently; they depended to a certain extent on the fact that antelope, as we have noted, are not particularly adept at staying away from man and, in fact, "are drawn by curiosity toward strange objects" (*ibid.*:111). We are probably not being too incautious in seeing parallels to both these activities in the Early Ajuereado phase.

Late Ajuereado Phase (*7000–6500* B.C.)

During this period, trips were made throughout both the rainy and dry seasons to the Coxcatlan thorn forest (Subarea 3) for deer hunting, trapping of cottontail, skunk, and probably other small animals, and the snaring of quail, other small birds, and lizards. Deer hunting and rabbit trapping also took place on the edge of the valley floor near the El Riego springs.

In spite of the presence during this period of a completely modern fauna, stone artifacts are identical to those of the Early Ajuereado phase (MacNeish, personal communication). Material culture, therefore, seems to have lagged behind any "readaptation" to the modern fauna. The changes we see are mostly behavioral: with the vanishing of the antelope and Pleistocene jack rabbit, there is no longer even a suggestion of communal game drives. Smaller groups seem to have done the hunting. Steward had already observed that, in arid North America at least, deer were not usually hunted by the same techniques that worked best on antelope. The latter were most efficiently hunted by surrounds and large cooperative drives, while deer (like nonmigratory game occurring in small and scattered groups) are better hunted by "small groups of men who know their territory well" (Steward 1955: 38–41). The pattern in Late Ajuereado times would seem to substantiate this observation.

Aside from this, we doubt that much "readaptation" was necessary as regards the trapping of small game. As Fig. 95 shows, when Pleistocene fox vanished, the prehistoric residents of the valley began trapping gray fox (*U. cinereoargenteus*); when Pleistocene quail disappeared, they began eating bobwhites; when the large Early Ajuereado turtles vanished, they began eating mud turtles; rodents like *Cratogeomys* probably replaced the extinct small ground squirrel; and the stream of Audubon cottontails continued uninterrupted. The vanishing of the "megafauna" in the Tehuacan Valley led to a shift from larger to smaller hunting bands, but in no sense triggered a change from a so-called "paleo-Indian" to an "archaic" way of life.

El Riego Phase (*6500–4900* B.C.)

During the rainy season, groups of macrobands came together in Subarea 3 to exploit the abundant resources of that particular time of year. Their activities included the hunting of deer and peccary and the trapping of cottontail, fox, skunk, bobcat, and other small game. They also ate lizard and quail. They made short-term hunting forays into Subarea 4, where they killed a few deer and brought them to Purron and Abejas caves; they trapped a few rabbits, ate a few birds and lizards, and then probably moved on, following the deer. They made brief trips into Tecorral Canyon where they picked up rabbits, gophers, and mud turtles. They did some fishing in the Rio Salado, and probably collected a few more mud turtles there.

With the coming of the dry season, the pattern changed. Most of the deciduous vegetation had turned brown or lost its leaves, and the male deer had fallen in with the females, making intensive deer-hunting profitable. Small hunting bands camped repeatedly in Subarea 3, stalking deer through the fall and winter and occasionally snaring quail, doves, and cottontails. On the valley floor, probably throughout the year, they hunted deer and cottontail. The general characteristics of the El Riego phase include an increase in deer hunting over previous periods and a bone-smashing technique which suggests extensive use of bone marrow. Both these activities suggest a fuller and more efficient adaptation to the modern fauna of the valley than we see in Late Ajuereado times.

Coxcatlan Phase (*4900–3500* B.C.)

During the rainy season, groups of people camped in Tecorral Canyon, where they trapped cottontails and gophers and collected turtles and lizards. They did little or no hunting, perhaps since the primary purpose of these camps was the planting and harvesting of the corn found in San Marcos Cave in levels dating to this phase. Late in the rainy season, they made short trips to Subarea 3 to hunt deer and trap

cottontails and other small game. They collected and ate a few lizards at this time.

During the dry season, hunting bands stayed for long periods of time in the Coxcatlan thorn-forest area. These bands practiced intensive hunting of deer, occasional hunting of peccary, and some minor trapping of birds, cottontails, and other small game. They made wide-ranging forays into Subarea 4, primarily to hunt deer, which often seem to have been brought from a great distance to Purron and Abejas caves. While briefly camped in this area, the group did some trapping of cottontails and birds. They fished occasionally in the Rio Salado. On the valley floor (probably throughout the year), they trapped many cottontails and jack rabbits, did some deer hunting, and ate doves and other birds. The general characteristics of the Coxcatlan phase included a shift away from long rainy-season camps in the mountains as agriculture began to affect food production, and an abandonment of the typical El Riego butchering technique which involved the meticulous smashing of deer long bones for marrow. Intensive deer hunting in the dry season continued.

Abejas Phase (3500–2300 B.C.)

Many continuations of the Coxcatlan hunting pattern are seen in the Abejas phase. During the rainy season, camps were made in Tecorral Canyon (and probably along most wet arroyos where planting could be done) and meat was procured by some trapping of cottontail and skunk, collecting of turtle and lizard, and snaring of doves and other birds. It may be that man was spending a greater part of the rainy season on the valley floor and adjoining wet canyons now that agriculture was more fully developed. Fishing was done in the Rio Salado, and a few brief camps (probably late in the rainy season) were made in Subarea 3 for the hunting of deer and trapping of cottontails, foxes, and probably other small game.

Once again, during the dry season, long-term macroband camps were made in the Coxcatlan area, with intensive hunting of deer and some peccary. The trapping of cottontail, raccoon, skunk, and birds was carried on as a minor activity. It may be that the brief trips evidenced in the Arroyo Lencho Diego (Subarea 4), during which deer and cottontail were obtained, can be traced to the dry season also; but for this we have no concrete evidence. The significant development in the Abejas phase is the first appearance in the Tehuacan Valley of domestic dog, now probably added to the food supply and certainly recorded from two cave sites in different subareas. General characteristics of the phase include an intensification of deer hunting in the dry season.

Purron Phase (2300–1500 B.C.)

So little evidence is available from this phase that no reconstruction of the hunting pattern is possible. We know only that there were brief camps in Subarea 4 where rabbits, skunks, and birds were eaten.

Ajalpan Phase (1500–900 B.C.)

By the Ajalpan phase, year-round residence in permanent villages on the valley floor was the rule, although bands of hunters and collectors appear to have been sent out seasonally to gather wild fruits and animals as a supplement to agriculture. In contrast to the earlier phases, foraging bands took some of their food along with them on these trips, including, judging by the cave remains, dogs and probably also corn and squash.

During the rainy season, deer and peccary were hunted in the vicinity of the village, where cottontails were trapped and turtles and lizards were collected. Many village dogs were eaten. In the dry season, hunting of deer and peccary was intensified, many turtles were collected, and more dogs were eaten. A few birds and small mammals also seem to have been trapped.

In addition, small foraging parties passed through Tecorral Canyon, picking up an occasional cottontail on the way. Brief camps were made in Subarea 4 by Ajalpan villagers, who ate the dogs they had brought with them, while hunting deer and trapping a few cottontails. General characteristics of the Ajalpan period include considerable seasonal deer hunting, increased use of one domestic meat source, and in villages near the Rio Salado, a steady collecting of mud turtles.

Santa Maria Phase (900–200 B.C.)

At the beginning of the Santa Maria phase considerable deer hunting was still being done in the vicinity of the village; peccary were also taken. This activity dwindled toward the end of the phase, and by 200 B.C. hunting was a relatively minor activity which was never to regain the importance of preceramic and early Formative times. Dogs were eaten on the largest scale ever in the villages of this phase. There was renewed interest in the trapping of cottontail, jack rabbit, gopher, and quail in the vicinity of the village, supplemented by turtle-collecting and the occasional taking of small game like raccoon, skunk, raven, hawk, and other forms.

During all seasons of the year, large parties traveled to the thorn forest around Coxcatlan. Remains in the

caves suggest that these were probably mainly excursions to collect wild seasonal fruits, but the groups involved also trapped cottontail, hunted deer and peccary, and captured skunks, iguanas, smaller lizards, and birds. During the dry season, other groups camped in the vicinity of the El Riego springs, trapped opossum and cottontail, hunted deer, and ate the dogs they had brought with them. During the construction of the dam near Purron Cave, large groups seem to have camped in Subarea 4, where they carried on extensive trapping of cottontails, hunted deer, and also picked up gophers, iguanas, quail, and other birds.

Palo Blanco Phase (200 B.C. to A.D. 700)

No villages or towns of this phase have been excavated, so we have no evidence of the hunting pattern in the vicinity of the towns themselves. There are many campsites, however, reflecting the greatly increased population of the valley at this time. Another domestic meat source, the turkey, was introduced into the Tehuacan Valley during the middle of the Palo Blanco phase (*ca.* A.D. 180).

During both rainy and dry seasons, there seem to have been very large camps at El Riego, near the edge of the valley floor, where many cottontails were trapped, as well as gophers, jack rabbits, opossums, foxes, lizards, snakes, turtles, and other small game. These groups, perhaps hunting with the bow and arrow now, took many deer and peccary, and ate numbers of dogs they had brought with them. Sizable camps were made during the rainy season in the wet canyons in Subarea 2 by foragers who ate cottontail, fox, gopher, lizard, snakes, and birds; hunted a few deer and peccary; and cooked some of their dogs. Campers during the rainy season in Subarea 4 trapped cottontail and hunted deer, ate a few dogs, and picked up an occasional fox, skunk, bird, iguana, or smaller lizard. Finally, late in the rainy season, big groups who may have been mainly plant collectors traveled to the Coxcatlan thorn forest, where they trapped cottontail, hunted deer and peccary, and ate many of the dogs and turkeys brought with them. Perhaps as a sideline to their other collecting activities, they caught a few foxes, skunks, gophers, birds, iguanas, and smaller lizards.

Our general impression of the Palo Blanco phase is that it was a time of plenty, with a rich and varied diet composed both of domestic and of wild foods. An increased use of domestic meat sources made big-game hunting of even less importance than it had been in the Formative phases. The rainy-season collecting and trapping camps seem to involve large numbers of people, assembled for all or most of a season, with stores of domestic meats and vegetables to help support them during this period.

Venta Salada Phase (A.D. 700 to the Conquest)

Only three small levels from Postclassic villages on the valley floor were excavated by the Tehuacan Project. They show that trapping of cottontails and other small game, as well as some hunting of deer, occurred in the vicinity of the village, while the eating of domestic turkeys and dogs continued. Consumption of turkey, in fact, seems to have increased during this phase, probably reaching its peak just at the time of the Conquest.

Many campsites from this period represent groups sent out from the villages, towns, or cities. As in the Palo Blanco phase, few of these can be definitely traced to the dry season by means of animal remains, but rainy-season collecting-and-trapping camps were very big indeed. Foragers in large camps on the edge of the valley floor, near El Riego springs, intensively trapped cottontails and hunted some deer and peccary throughout the year. They also ate turkeys and dogs in quantity. During the course of their stay, it appears that their trap lines also picked up opossums, skunks, and jack rabbits; and one way or another they obtained gophers, rock squirrels, turtles, birds, and small lizards. Late in the rainy season, sizable camps were made in Subarea 3, where white-tailed deer were hunted and cottontails, foxes, skunks, opossums, bobcats, and gophers were trapped. The campers ate many of the dogs and turkeys brought with them, and rounded out their meat diet with iguanas and other lizards, and many different kinds of birds.

Brief camps, for which we have no seasonal evidence, were made in Tecorral Canyon, where cottontails, gophers, and skunks were trapped, peccary hunted, and small birds eaten. The general characteristics of the phase include a tendency for big rainy-season collecting-and-trapping camps and a slight increase in the eating of turkey and wild birds when compared with the earlier phases.

Conclusions

1. Man was present in the Tehuacan Valley 10,000 years ago as a contemporary of horse, antelope, jack rabbit, fox, small ground squirrel, gopher tortoise, and other forms suggesting a climate like that of the arid-temperate plateau of northern Mexico today. During this era he lived primarily on small game, though remains of large fauna are also present in his campsites. There is evidence for communal jack rabbit drives.

2. The change to a modern climate and fauna was essentially complete by 7000 B.C. Since that time, as suggested by the lack of variation in small rodent remains, the basic ecology of the valley has not altered. Today the northern end of the valley is classified as semi-arid temperate, and the southern end of the valley as arid tropical.

3. During the period from 6500 to 1000 B.C., subsistence involved considerable hunting of white-tailed deer, especially in the dry season, and cottontails of two species were trapped in great numbers. These two animals, deer and cottontail, have remained the most important wild meat sources in the valley.

4. The domestic dog was introduced into the Tehuacan Valley at about 3200 B.C., in the agricultural late preceramic Abejas phase. To the best of our knowledge, this is the oldest reliably dated evidence for dog in Mesoamerica proper. From at least 1500 B.C. on, there is abundant evidence that this animal was eaten.

5. The domestic turkey was introduced into the Tehuacan Valley at about A.D. 180, in the Classic, or Palo Blanco, period; from this time on, it was used as food. To the best of our knowledge, this is the oldest reliably dated evidence for domestic turkey in Mesoamerica proper.

6. Hunting continued in the later periods (900 B.C. to A.D. 1500), but never on the scale seen in prepottery times. Trapping of such forms as cottontail and gopher continued, but at the time of the Conquest domestic animals represented at least 20 percent of the individual animals eaten in the valley.

A Note on the Stomach Contents of Animals Collected in the Tehuacan Valley, 1962

By Eric O. Callen

The material analyzed below was obtained from small animals collected by Kent V. Flannery between June and August 1962 in and around the caves and archaeological sites of the Tehuacan Valley. Stomach contents of the larger animals collected were not available for analysis. The material was first washed in water and then preserved in methylated spirit, stopping further digestion or decay. Any material requiring microscopic examination for identification purposes was mounted in glycerine jelly on a standard-sized microscope slide. The jelly contained a little phenol as a preservative. It is hoped that more definite identification of much of the material can be made at a later date.

Mammals

Order Marsupialia

FAMILY DIDELPHIDAE

Didelphis marsupialis (opossum), Specimen T–16. Collected: June 21, 1962, near Calipan. Contained: (1) Plant material—a great many corn seeds; mesquite (*Prosopis juliflora*) seeds and pods; a number of tree-legume leaves, almost certainly those of mesquite; a single large solanaceous seed, possibly *Capsicum;* other small solanaceous seeds; the base of a dicotyledon leaf, not mesquite. (2) Animal material—among various fragmentary insect remains, parts of a beetle wing cover and abdomen could be recognized. (3) Mineral material—nil.

Order Lagomorpha

FAMILY LEPORIDAE

Sylvilagus audubonii (Audubon cottontail), Specimen T–23. Collected: June 27, 1962, near Calipan. Contained: (1) Plant material—fruits of *Castela tortuosa* and the epidermis of what is probably either the fruit or leaf thereof; several types of trichomes, including compound stellate ones (see Mexican cottontail, Specimen T–22); chewed grass and probably corn leaves. (2) Animal material—nil. (3) Mineral material—nil.

Sylvilagus cunicularius (Mexican cottontail), Specimens T–14 and T–15. Collected: June 21, 1962, near Calipan. Contained: (1) Plant material—the remains of a pod and a number of seeds of a tree legume, not mesquite; the rest was a mixture of finely chewed grass and legume pod. (2) Animal material—nil. (3) Mineral material—nil.

Sylvilagus cunicularius (Mexican cottontail, juv.), Specimen T–22. Collected: June 27, 1962, near Calipan. Contained: (1) Plant material—well-chewed grass and corn leaves, compound stellate trichomes, and a fragment of dicotyledon leaf. (2) Animal material—mammal hair. (3) Mineral material—nil.

Order Rodentia

FAMILY SCIURIDAE

Citellus (Spermophilus) mexicanus (gray rock squirrel), Specimen T–20. Collected: June 26, 1962, from El Riego cliffs. Contained: (1) Plant material—three large seeds and some fruit epidermis, neither of which have yet been identified; *Opuntia* seeds and tissue; what appear to be mesquite seeds; and seed coat and part of the pod of a tree legume. (2) Animal material—nil. (3) Mineral material—nil.

FAMILY HETEROMYIDAE

Liomys irroratus (spiny mouse), Specimens T–31 and T–32. Collected: July 8, 1962, from the stomach of a bobcat, freshly eaten. Contained: (1) Plant material—one seed of mesquite, two seeds of *Vallesia glabra*, and one seed of *Opuntia.* (2) Animal material—nil. (3) Mineral material—nil.

FAMILY CRICETIDAE

Peromyscus melanophrys (deer mouse), Specimen T–41. Collected: August 2, 1962, near Coxcatlan Cave. Contained: (1) Plant material—apparently nil. (2) Animal remains—

well-chewed remains of many arthropods, showing dark brown and magenta color in or under the chitin. (3) Mineral material—some hardened matter that might have been wax eomb.

Order Carnivora

Family Procyonidae

Bassariscus astutus (ring-tailed cat), Specimen T–26. Collected: June 30, 1962, near Calipan. Contained: (1) Plant material—exclusively seeds of mesquite and fruits and seeds of *Vallesia glabra.* (2) Animal material—three crickets (one male, two female), several small beetles, one very large beetle, and one arachnid (probably a scorpion). (3) Mineral material—nil.

Procyon lotor (raccoon), Specimen T–27. Collected: July 2, 1962, near Calipan. Stomach empty; intestine contained: (1) Plant material—*Opuntia* seeds, epidermis, trichomes, and tissue; a piece of plant epidermis with closely packed, sunken glands; a few stomata; and a single three-cornered seed (Family Polygonaceae). (2) Animal material—mammal hair and a single insect abdomen, badly damaged. (3) mineral material—a few small stones, i.e., gravel.

Family Mustelidae

Mephitis macroura (striped skunk), Specimen T–17. Collected: June 22, 1962, near Calipan. Contained: (1) Plant material—nil. (2) Animal material—wings and parts of a large beetle, parts of a pseudoseorpion, and many larvae, probably belonging to a beetle of the Family Scarabaeidae. These larvae are probably those of the white grub (*Phyllothopa*), one of the June beetles. Among the grubs were also numerous nematodes of the genus *Physaloptera, sensuo lato.* In addition, the wings of several small beetles were found. (3) Mineral material—nil.

Reptiles

Order Chelonia

Family Kinosternidae

Kinosternon integrum (mud turtle), Specimen T–21. Collected: June 27, 1962, from Rio Salado. Contained: (1) Plant material—nil. (2) Animal material—a single large water beetle, probably of the genus *Belostoma,* as well as the wings and body of an ichneumon fly. Among some mud were the remains of medium and small-sized water-snail shells. Two termite wings were also present. (3) Mineral material—mud.

Order Squamata

Family Iguanidae

Ctenosaura pectinata (black iguana), Specimen T–5. Collected: June 18, 1962, near Ajalpan. Contained: (1) Plant material—four large, reddish-brown fruits, and the tough exterior of a drupaceous fruit, neither of which has been identified. (2) Animal material—nil. (3) Mineral material —nil.

Ctenosaura pectinata (black iguana), T–7. Collected: June 20, 1962, from Rio Salado area near Calipan. Contained: (1) Plant material—the remains of a number of *Vallesia glabra* fruits, seeds, flowers and buds, as well as inflorescence stalks. There were also three large, fat, almost beanlike seeds, one of which had apparently come from a large, tough drupaceous fruit, densely covered with stellate hairs. These seeds and the fruit contained a curiously luminescent orange material. (2) Animal material—three soil nematodes, a robber fly, probably of the genus *Bombomina,* and 30 small spiders. (3) Mineral material—nil.

Birds

Family Phasianidae

Colinus virginianus (bobwhite quail), Specimen T–2. Collected: June 18, 1962, near Ajalpan. Contained: (1) Plant material—all one kind of seed, with the seeds grouped together into groups of three or four, reminiscent of sugar beet; but the presence of flower parts rather suggests the mint family. (2) Animal material—a single small spider. (3) Mineral material—nil.

Family Columbidae

Zenaida asiatica (white-winged dove), Specimens T–9 and T–10. Colleeted: June 20, 1962, near Venta Salada. Contained: (1) Plant material—fruits and seeds of *Vallesia glabra;* five seeds of what at first looked like corn, but may be some type of bean; one seed of *Riccinus,* the castor oil plant; five seeds of some large drupeacous fruit; pieces of another fruit as yet unidentified. (2) Animal material—nil. (3) Mineral material—nil.

Zenaida asiatica (white-winged dove), Specimen T-24. Collected: June 30, 1962, from the Coatepec site near Ajalpan. Contained: (1) Plant material—what appear to be the remains of "tuna" (cactus fruit), plus fragments of a hard, brown seed coat. The seeds are both the young and mature seeds of a single kind of cactus, probably either *Pilocereus* or *Cephalocereus.* (2) Animal material—nil. (3) Mineral material—nil.

Zenaida asiatica (white-winged dove), Specimen T–36. Collected: July 25, 1962, near Coxcatlan Cave. The crop contained: (1) Plant material—a single seed of *Opuntia.* (2) Animal material—some 20 cutworms, half of them pale all over and the rest with dark dorsal and pale ventral surfaces. Mineral material—nil.

Zenaida asiastica (white-winged dove), Specimen T–38. Collected: July 28, 1962, near Coxcatlan Cave. The crop contained: (1) Plant material—nine largish fruits, not yet identified, and twelve seeds of *Opuntia.* (2) Animal material —nil. (3) Mineral material—nil.

Family Caprimulgidae

Caprimulgus ridgwayi (buff-collared nightjar), Specimen T–40. Collected: July 30, 1962, near Coxcatlan Cave. Contained: (1) Plant material—nil. (2) Animal material— remains of insects, many of them heads, of which a num-

ber were undoubtedly those of ants; also large insect abdomen which cannot be identified and the headless body of a long, thin-waisted insect. (3) Mineral material—nil.

Family Corvidae

Corvus corax (raven), Specimen T–12. Collected: June 20, 1962, from the Coatepec site near Ajalpan. Contained: (1) Plant material—a great many corn seeds and a good deal of corn silk. (2) Animal material—the remains of one cricket, one grasshopper, an ichneumon fly, numerous ants, and a carnivorous beetle. There were also bones of a small lizard, probably a race-runner (Family Teiidae). (3) Mineral material—nil.

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CHAPTER 9

Prehistoric Wild and Cultivated Maize

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Prehistoric remains of maize were found in five of the caves excavated in Tehuacan Valley: Coxcatlan, Purron, San Marcos, Tecorral, and El Riego. From several standpoints the prehistoric maize from these caves is the most interesting and significant so far discovered. (1) It includes the oldest well-preserved cobs available for botanical analysis. (2) The oldest cobs are almost certainly those of wild maize. (3) This maize appears to be the progenitor of two of the previously recognized ancient indigenous races of Mexico, Chapalote and Nal-Tel, of which prehistoric prototypes had previously been found in Swallow and La Perra caves respectively (Mangelsdorf *et al.* 1956; Mangelsdorf and Lister 1956). (4) Specimens of all parts of the plant were preserved, and these show beyond a reasonable doubt that the ancestor of cultivated maize was maize. (5) The collection portrays a well-defined evolutionary sequence covering a period of about 6500 years.

The finding of prehistoric wild corn in the environmental setting of the Tehuacan Valley is in some respects quite surprising. Maize is not notable for its drought resistance, and in order to thrive it requires a steady and adequate supply of water. For this reason, among others, Mangelsdorf and Reeves (1939) postulated that wild maize, if still extant, should be found in the humid regions of the tropics and subtropics. At first glance the Tehuacan Valley, with its arid climate and its predominantly xerophytic, drought-resisting vegetation comprising cacti and thorny leguminous shrubs, did not appear to be a suitable habitat for wild corn. Actually Mangelsdorf had visited this valley a number of times beginning in 1941, and at no time had it occurred to him that wild corn might once have grown there. Closer examination of the environmental factors, however, suggests that the habitat furnished by this arid valley may, in fact, have been almost ideal for wild corn. The average annual rainfall in the valley is low (approximately 500 mm. per year at the valley's center). More important than the total rainfall, however, is its seasonal distribution. About 90 percent of the annual rain falls during the growing season from April through October. It reaches its peak in midsummer, during corn's most critical period when it would normally be silking, shedding pollen, and the young kernels developing.

The remaining months are quite dry—in midwinter the valley is virtually a desert—and comprise a period during which the seeds of wild maize and other annual plants could have lain dormant ready to sprout with the beginning of the summer rains—never in danger of germinating prematurely only to succumb to the vicissitudes of winter. Seeds of many wild plants have mechanisms for delaying germination, devices which provide protection against this danger, but corn—at least modern corn—has no such characteristic, perhaps because it evolved in an environment where none was needed. Such is the environment of Tehuacan. The perennial vegetation of this valley, which year after year must survive the dry winter months, is necessarily xerophytic. The annual vegetation, which grows only during the rainy season, need not be especially drought resistant. Nor need the wild corn have been subjected to severe competition with the drought-resistant peren-

Fig. 96. Cobs of wild corn (Coxcatlan phase, San Marcos Cave, actual size) are characterized by uniformity of intact cobs, relatively long glumes, and fragile rachises.

nial vegetation. The sites which are most suitable for corn, the alluvial terraces and fans of the canyons and barrancas, seem not to be well adapted to the growth of cacti and shrubs. Indeed the deeper the alluvial soil the less likely are the cacti and shrubs to be found growing on it. Instead there are grasses and other annual plants among which wild corn might have been quite at home.

In all, 24,186 specimens of maize were found in the five caves; 12,860 of these, or more than half, are whole or almost intact cobs. There are, in addition to the intact cobs, 3,941 identified cob fragments and 3,878 unidentified cob fragments. Among the remaining specimens are all parts of the corn plant: 46 roots, 506 pieces of stalks, 442 leaf sheaths, 282 leaves, 245 inner husks, 706 outer husks, 12 prophylls, 127 shanks, 384 tassel fragments, 47 husk systems, 5 midribs, and 797 kernels. There are also numerous quids, representing 83 chewed stalks or leaves and 140 chewed husks.

Botanists studying a collection of prehistoric specimens of maize are usually confronted with the problem of where best to begin. In undertaking our study of the prehistoric maize from Tehuacan, we decided to concentrate first on the relatively limited collection from San Marcos Cave, totaling 1,248 specimens. Since the number of specimens was not large, it was possible to spread out the entire collection and view it as a whole. These specimens revealed a well-defined sequence showing how maize had evolved over a period of some 6500 years—how a wild grass with tiny ears had developed into a highly productive cultivated food plant. We hoped, too, that the study of this relatively small collection would provide a pattern for studying the much larger collection of over 15,000 specimens from Coxcatlan Cave. This not only proved to be the case, but it also turned out that the collection from San Marcos Cave tells virtually the whole story, the collections from the other caves adding little more than corroboration. (An additional 750 specimens came from Tc 272, Tc 255, and Tc 35e.) Consequently we propose to describe the specimens from San Marcos Cave in some detail and those from the remaining caves much more briefly.

San Marcos Cave, Zones F and E

From Zone F, representing the early part of the Coxcatlan phase and dating to nearly 5000 B.C., there is one small cob. Since this specimen is essentially like the cobs from Zone E, it probably represents only a very slightly earlier part of the Coxcatlan phase than the latter zone. The following description of the cobs from Zone E applies also to this single specimen.

The maize from Zone E consists of 26 cobs or fragments of cobs. A number of these are illustrated in Fig. 96. These cobs are remarkably uniform not only in size but also in their botanical characteristics. Of eight cobs which are apparently intact with respect to length, the shortest is 19 mm. and the longest 25 mm. The number of rows of kernels is usually eight, but one cob is distichous with four rows and another has eight rows in the basal and four in the apical region. The number of functional spikelets per row varies from six to nine, and the total number of spikelets (estimated by multiplying row number by number of spikelets) varies from 36 to 72. The average number is 55.

The glumes of the spikelets are rather long in relation to other structures and are soft and herbaceous rather than horny and indurated. In some cobs the glumes are folded back, probably as the result of the removal of the kernels. The general aspect of these early cobs is that of a weak form of pod corn similar to that of a genotype of modern pod corn involving the $tu1^h$ allele at the tunicate locus on chromosome 4 combined with the tunicate inhibiting factor, *Ti*, on chromosome 6. When examined under a dissecting scope these cobs produce an impression of pod corn from which the kernels have been removed. A photo-

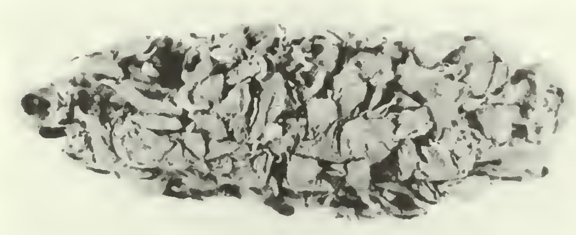

Fig. 97. An intact cob from Fig. 96 magnified to show the long soft glumes and the general impression of pod corn (x 3.0).

graph of one of these cobs taken at low magnification is reproduced in Fig. 97.

The spikelets, which are uniformly paired as in modern corn, are attached to cupules which are as long as they are broad or longer, fleshly rather than indurated, and almost glabrous, bearing only sparse short hairs.

The rachis consists of individual cupules joined together at their sides and ends. The cross section of the rachis of an eight-rowed ear thus has the appearance of a square with flaring corners. The rims of the cupules form the structures which in modern maize are sometimes referred to as "rachis flaps." In the earliest San Marcos maize these are quite prominent. The adjoining cupules are not tightly bound to one another so that the rachis disarticulates rather easily and is by no means as rigid as the rachises of modern maize.

The majority of the ears represented by these cobs were originally bisexual, bearing pistillate spikelets below and staminate spikelets above. Of the fifteen apparently intact cobs, ten had recognizable stumps at their tips where a staminate spike had presumably been broken off. Others may also have had staminate spikes, since it is not always possible to distinguish between the stump of a staminate spike and the broken end of a cob which has lost one or more of its terminal pistillate spikelets.

In bearing both male and female spikelets in the same inflorescence, the prehistoric wild corn resembles our genetically reconstructed ancestral form (Mangelsdorf 1958*a*) as well as certain primitive races of modern corn, Nal-Tel and Chapalote of Mexico (Wellhausen *et al.* 1952), Pollo of Colombia (Roberts *et al.* 1957), Confite Morocho of Peru (Grobman *et al.* 1962), and corn's wild relative, *Tripsacum*, which regularly bears pistillate spikelets below and staminate spikelets above on its lateral spikes.

The earliest cobs—27 from San Marcos Cave and 44 from Coxcatlan Cave, some of which date to nearly 5000 B.C.—are regarded as being those of wild maize for six reasons. (1) They are remarkably uniform in size and other characteristics and in this respect resemble most wild species. (2) The cobs have fragile rachises as do many wild grasses; these provide a means of dispersal which modern corn lacks. (3) The glumes are relatively long in relation to other structures and must have partially enclosed the kernels as they do in other wild grasses. (4) There are sites in the valley, such as the alluvial terraces below San Marcos Cave, which are well adapted to the growth of annual grasses, including corn, and which the competing cacti and leguminous shrubs appear to shun. (5) There is no

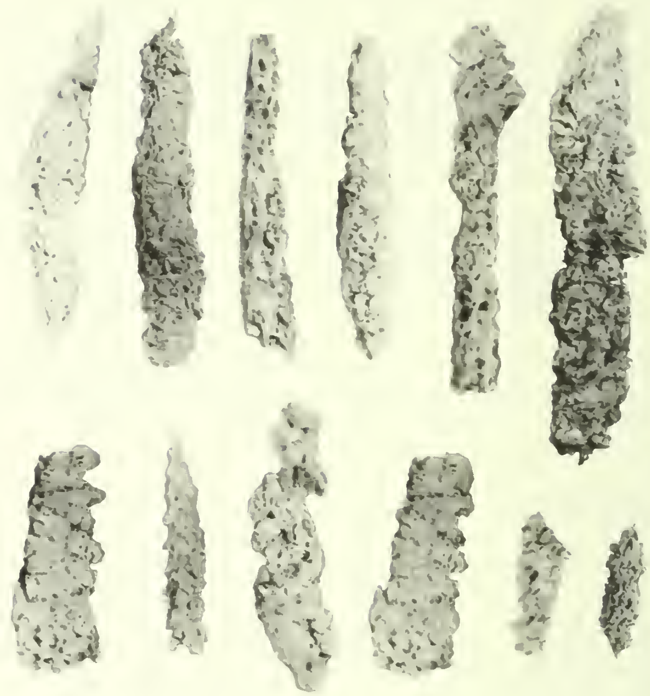

Fig. 98. Cobs of early cultivated corn (Abejas phase, San Marcos Cave, actual size) are larger and more variable than cobs of wild corn but are similar in having long glumes and fragile rachises.

firm evidence from other plant species that agriculture had yet become well established in this valley, at least in the earlier part of the Coxcatlan phase. (6) The predominating maize from the following phase, Abejas, in which agriculture definitely was well established, is larger and more variable than the earliest corn.

This combination of circumstances leads to the conclusion—an almost inescapable one—that the earliest prehistoric corn from the Tehuacan caves is wild corn. We have assumed here that it is.

These cobs represent the first ears of wild maize so far discovered. However, still earlier evidence of the existence of maize in the form of fossil pollen has been found in the Valley of Mexico (see Barghoorn *et al.* 1954, and Irwin and Barghoorn 1965).

The separation of the staminate and pistillate spikelets, the regular pairing of the pistillate spikelets, and the relatively soft tissue of the rachis and the glumes all provide convincing evidence that the wild ancestor of cultivated corn was corn and not one of its relatives, teosinte or *Tripsacum*. Together with the much earlier fossil pollen from the Valley of Mexico, these prehistoric cobs from the Tehuacan Valley provide virtually conclusive evidence that corn is an Amer-

Fig. 99. Cob of early cultivated corn (Abejas phase, San Marcos Cave; x 1.6). The slender rachis and relatively long glumes are characteristics of weak forms of pod corn.

ican plant and not of Asian origin as some writers have suggested (Stonor and Anderson 1949).

San Marcos Cave, Zone D

Cobs

From this zone representing the earlier part of the Abejas phase, which extended from about 3500 to 2300 B.C., 102 cobs or fragments of cobs were recovered. All but one of these, described below, were similar in their general characteristics to the 27 specimens from Zones E and F, but the majority were larger. The characteristics of ten totally intact cobs from this zone are set forth in the accompanying tabulation. A number of the cobs are illustrated in Fig. 98.

	Length in mm.	*No. of rows*	*Spikelets per row*	*Total spikelets*
	28	8	8	64
	30	8	8	64
	32	8–10	10	90
	40	8	11	88
	44	8	16	120
	44	8	17	136
	45	8	12	106
	51	8	17	136
	55	8	18	144
	61	10	19	190
Average	43.0	8.3	13.6	113.8

Not originally assigned to Zone D but obviously belonging to it is a collection of 43 cobs from Zone C[1] which are quite similar to those described above. One of these cobs which is intact with respect to length is 49 mm. long, has eight and ten rows, 15 spikelets per row, and a total of about 135 spikelets.

Fig. 100. Cobs of early cultivated corn (Abejas phase, San Marcos Cave; x 1.8). *Left:* a rachis of an eight-rowed cob with floral bracts removed showing the long relatively shallow cupules and lack of compression. *Right:* intact cob of a similar ear.

In the structure and texture of the glumes and cupules, these cobs, altogether 145 in number, are quite similar to those in the earlier Zones F and E. Their characteristics are illustrated in Figs. 99 and 100. Their larger size indicates, however, that they were grown in a better environment. Since these larger cobs came from levels in which were found remains of two species of squashes (*Cucurbita moschata* and *C. mixta*), tepary and common beans (*Phaseolus acutifolius* and *P. vulgaris*), bottle gourds (*Lagenaria siceraria*), chili peppers, avocados, and amaranths, it is assumed that they represent the product of an improved environment resulting from the practice of agriculture—that maize had at this stage been domesticated and become a cultigen. Consequently we are designating this maize as "early cultivated."

If this maize from Zone D is indeed cultivated maize, it is noteworthy that domestication had effected little change except in size. In its botanical characteristics the early cultivated maize is virtually identical with wild maize from which it stemmed. And if the longer cobs do indeed represent cultivated maize then it seems all the more likely that the smaller cobs from the lower zones represent maize grown in the wild.

The one exceptional cob, a fragment mentioned

Table 21. Maize Remains from All Sites by Zone and Phase

	Cobs, all races	Kernels, all races	Roots	Stalks	Leaf sheaths	Leaves	Inner husks	Outer husks	Prophylls	Shanks	Tassels	Husk systems	Midribs	Quids (husks)	Quids (leaves or stalks)	Totals
Venta Salada																
Tc 35e, A	895	158	1	26	13			9			33			1		1136
Tc 50, I	1380	16	18	40	39	8	17	44	9	4	17	5		11		1608
Tc 50, II	2273	21	2	2	93	65	82	68		64	40	5		4	18	2737
Tc 35e, B	841	215	2	35	18		4	13		4	14	5				1151
Tc 50, III	4115	3	4	125	103	54	119	227		29	54	16		13	17	4879
Tc 255, A	56			54				24							2	136
Tc 35e, C	2613	2	2	8	13	35	9	2		16	22			4	8	2734
Palo Blanco																
Tc 35e, D	959	323	2	26	3	5		24		1	5					1348
Tc 35e, E	140			1		4		2							1	148
Tc 50, IV	1793	1	1	48	10	48	1	98			122	1	3		1	2127
Tc 254, B	447	4		43	79	17	9	36	3	6	33			26	32	735
Tc 254, C[1]	134															134
Tc 50, V	639	7		4	5	4		13			7	5			1	685
Tc 272, A	200							4						6	2	212
Tc 272, B	97	3		1										4		105
Tc 272, C	160	1		5	4			3		1		1		1		176
Tc 272, D	67			4		6		6						8		91
Tc 272, E	170		4			3		4		1				4		186
Tc 50, VI	2302	4	3	54	15	10		78		1	25	4	1			2497
Tc 272, F	29	3		1				3			3					39
Santa Maria																
Tc 50, VII	592	32		14	24	12		36			7	1			1	719
Tc 272, G	30		2		3									2		37
Tc 272, H	12													13		25
Tc 272, I	10													11		21
Ajalpan																
Tc 254, C	174		5	14	20		4	11			1					229
Tc 272, J	12	1				1								6		20
Purron																
Tc 272, K[1]	1	3														4
Tc 272, K	2															2
Abejas																
Tc 50, VIII	15											1		8		24
Tc 50, IX	27					4						2				33
Tc 254, D	102					1		1			1?			9		114
Tc 50, X	2															2
Coxcatlan																
Tc 50, XI	25			1		5						1	1			33
Tc 254, E	26													9?		35
Tc 254, F	1															1
Tc 50, XII	5															5
Tc 50, XIII	18															18
Totals	20,364	797	46	506	442	282	245	706	12	127	384	47	5	140	83	24,186

Fig. 101. *Left to right:* fragment of a stem, a husk system, a cob, and a staminate spike from early zones of San Marcos Cave.

above, must now be accounted for. It is larger in diameter than the cobs of early cultivated maize and has strongly indurated tissues of its rachis and glumes. It resembles a type which is quite common in Zone C and will be described below. This cob, however, seems to represent the beginning of a new race—early tripsacoid—as similar cobs were found in contemporaneous levels of Coxcatlan Cave (see Table 22).

Husks

Associated with this collection was an almost intact husk system which yielded a surprising amount of information. Its shank or peduncle was broken immediately below the lower leaf sheath and has a diameter of 4 mm. The shank has two nodes 4 mm. apart. Since a fragment of an ear bearing the floral bracts of two pistillate spikelets is attached immediately above the upper node, it is certain that the upper leaf sheath of this specimen must have been the uppermost leaf sheath of the original husk system. That the lower leaf sheath of the specimen was the lowermost husk and therefore the outer husk of the original system is less certain, although it does have the aspect of an outer rather than the inner husk, as the description below suggests. Both husks appear to be intact with respect to length, although they are somewhat frayed at their tips. The lower one is 90 mm. long and the upper 50 mm. Both have conspicuous venation, the lower one having more prominent veins than the upper. The ridges of the lower husk bear short hairs, and the surface and margins of the upper husk have scattered long hairs. Neither husk is terminated by a ligule and leaf blade, as are the husks of many modern varieties

Fig. 102. Staminate spikelets of a tassel fragment (Coxcatlan phase, San Marcos Cave; x 1.6). The glumes are soft, membranous, and glabrous.

of corn. The husks are illustrated in Fig. 101, which also shows a cob and a section of stalk.

Because these two husks differ in their venation and hairiness, we have assumed that one is the outer and the other the inner of a two-husk system. Ears with few husks are usually borne in the upper part of the stalk, sometimes immediately below the tassel. The husks protect the young ear before pollination and in the early stages of development but flare open at maturity, allowing the ear to disperse its seeds. Ears with few husks may also occur in lateral inflorescences in which ears are borne at secondary positions at the nodes of the peduncle. We are unable to determine whether this specimen represents the leaf sheaths of an ear borne high on the stalk or whether it was part of a branched lateral inflorescence.

Since the average length of the longer ears from this zone is about 50 mm., it appears that the inner sheath would have barely covered the pistillate portion of an average ear. If there was a terminal staminate spike, as the stumps at the apices of some cobs indicate that there may have been, the young spike would have been enclosed or partially enclosed by the outer husk, which probably opened before anthesis allowing the staminate spikelets to shed pollen. We have observed many ears of this type in extensive cultures of pod-popcorn representing our genetically reconstructed ancestral form.

Tassel Fragment

Found also in Zone D was a small fragment bearing staminate spikelets. The spikelets were arranged in two ranks, indicating that the spike was a lateral branch from a branched tassel. The spikelets occurred in pairs, one sessile and the other pedicellate; the glumes, which are 7.8 mm. in length, are thin, lacking in distinct keels, weakly veined, and completely glabrous. The branch is illustrated in Fig. 101. After this photograph was taken, we attempted to clean the specimen by dipping it in hot water. This caused most of the spikelets to separate from the rachis. Floating on the surface of the water, they provided a very interesting picture (Fig. 102), showing that the glumes are thin and translucent, quite different from the much thicker glumes of *Tripsacum* or teosinte. Thus in the staminate spikelets of the tassels as well as in the pistillate spikelets of the cob, the early corn from Tehuacan has exactly the same basic botanical characteristics as modern maize and furnishes additional evidence that the ancestor of cultivated corn was corn.

San Marcos Cave, Zone C

Cobs

The cobs of this zone, representing the Ajalpan phase which dates from 1500 to 900 B.C., included a new type similar to the single specimen described immediately above. Because of the indurated tissue of rachises and glumes, we have designated this type as "early tripsacoid." The term "tripsacoid" is one proposed by Anderson and Erickson (1941) to describe any combination of characteristics which might have been introduced into corn by hybridizing with its relatives, teosinte or *Tripsacum*. In both of these species the tissues of the rachis and the lower glumes are highly indurated and the lower glumes are thickened and curved. Archaeological cobs showing these characteristics are thus suspected of being the product of the hybridization of maize with one of its two relatives.

How this highly tripsacoid maize came into existence is still an unanswered question. There seems little doubt that it is the product of the hybridization of maize with teosinte or *Tripsacum*. Where did this occur? Neither teosinte nor *Tripsacum* is known in the Tehuacan Valley today, nor are there remains of either among the archaeological specimens. This does not, however, rule out completely the possibility that one or both species once grew in the valley. Another possibility is that early cultivated corn of Tehuacan was carried into other regions where it hybridized with teosinte or *Tripsacum*, and some of the hybrid progeny was later returned to the Tehuacan Valley. Both *Tripsacum* and teosinte occur widely today in the adjoining state of Guerrero. A third possibility is that wild

Fig. 103. Three types of cobs (Abejas phase, San Marcos Cave; x 1.6): early cultivated, with slender rachis and relatively long, soft glumes; early tripsacoid, with stiff indurated glumes; a possible hybrid of the two preceding types.

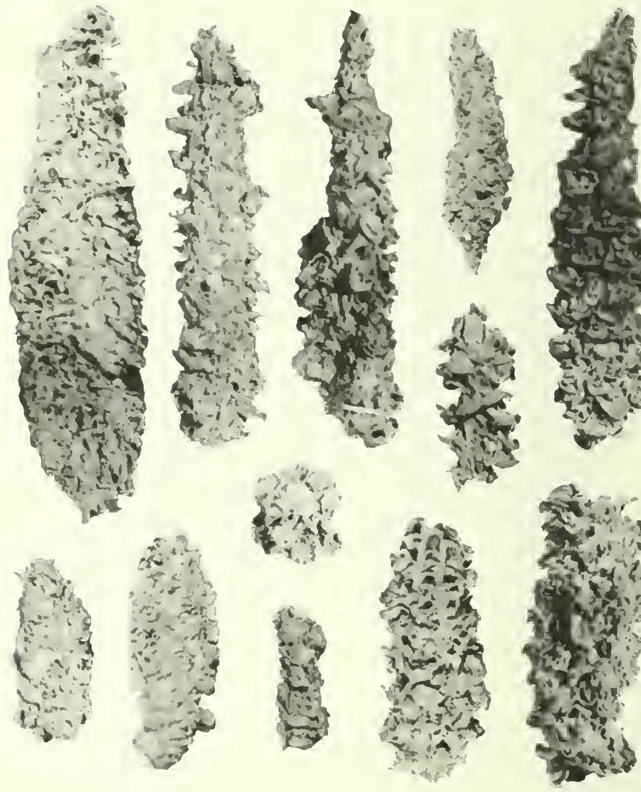

Fig. 104. Various hybrid combinations from the crossing of Tehuacan early cultivated corn with early tripsacoid corn and backcrossing to both parents. Actual size.

maize grew in other parts of Mexico, and once domestication began, hybridized with *Tripsacum* or teosinte to produce the new race "early tripsacoid." The fossil pollen from the Valley of Mexico described by Barghoorn *et al.* (1954) is evidence that wild maize once existed there. There may be still other possibilities. It is at least clear that as early as the Abejas phase a new element had been introduced into the maize complex in the Tehuacan Valley.

Whatever the origin of the early tripsacoid corn, it evidently hybridized with both the wild and early cultivated corn of the Tehuacan Valley to produce hybrids which in their cob characteristics were intermediate between those of the parents. First generation hybrids in turn crossed back to both parents to produce great variation in both the wild and cultivated populations (see Figs. 103–106).

One of the most conspicuous products of this presumed hybridization was a type which we have called "wild-type segregates." Cobs are about the size of cobs of the original wild corn but possess some of the characteristics, especially the indurated rachises and glumes, of the early tripsacoid putative parents. Specimens of these are shown in actual size in Fig. 106. A substantial proportion of the cobs are two-ranked like the spikes of *Tripsacum* and teosinte. These disarticulate readily, and in this respect some of the wild-type segregates may have been better adapted for survival in the wild than the original wild corn. In Table 22 the wild-type segregates are listed together with the early cultivated specimens, not because of a close genetic relationship, but because the two types would yield about the same amount of food.

Husks

Eleven pieces of outer husks intact in length have lengths of 90, 90, 90, 93, 100, 110, 114, 120, 120, 135, and 140 mm. These specimens are quite thick and conspicuously ridged compared to the inner husks. All are lacking in ligules and leaf blades. Most are glabrous, but several have sparse long hairs on the ridges.

Four pieces of inner husks have lengths of 90, 90, 120, and 120 mm. The two shorter pieces have profuse long hairs; the longer pieces are almost glabrous.

Fig. 105. Cobs from a single cache in San Marcos Cave, showing the great variation which followed hybridization of Tehuacan corn with early tripsacoid corn. The two cobs at upper right are wild-type segregates. Actual size.

Fig. 106. Wild-type segregates (Palo Blanco phase, Coxcatlan Cave, actual size). At lower left is a tassel branch with basal pistillate spikelets. Another specimen is distichous with several spikelets.

Leaf Sheaths

Of 20 specimens of leaf sheaths in this zone, 14 are completely glabrous. All of these are narrow, indicating that they had come from slender stems. Two of these are still attached to slender pieces of stalk. Three of the sheaths have sparse long hairs on the ridges, two have short hairs between the ridges, and one, the broadest of the lot, has profuse long hairs on the ridges and profuse short hairs between. The glabrous condition of the narrow sheaths is probably a characteristic of the wild type. No modern corn, known to us, has leaf sheaths as completely glabrous as the leaf sheaths of the early Tehuacan corn. Several of the sheaths are depicted in Fig. 107.

Stalks

In addition to the stalk pieces with attached roots to be described below, there are 14 other short pieces of stalks from this zone. These vary in diameter from 4 to 15 mm., with an average of 9 mm. Since the position of the pieces on the original plants is not known, there is no way of distinguishing the thicker basal pieces from the more slender apical pieces. However, even the thickest of the pieces, which may represent one of the lower internodes, is still quite slender compared to the basal internodes of modern corn.

Roots

Five specimens of basal-stalk fragments with roots attached provide some interesting bits of information. Four of these were intact (Fig. 108) and have diameters of 12, 11, 17, and 10 mm. respectively. These dimensions are considerably smaller than those of modern corn grown under agricultural conditions. The primi-

Fig. 107. Leaf sheaths (Palo Blanco phase, San Marcos Cave, actual size).

tive races of Colombia, Pollo and Pira, described by Roberts *et al.*, 1957, had minimum and maximum stem diameters slightly above ground level of 21.8–24.2 and 21.6–24.1 mm. respectively. The mesocotyls on two of our specimens were intact and were quite short, measuring 11 and 7 mm. Since the mesocotyl elongates during germination until the emerging seedling reaches the surface of the soil, this indicates that the kernels were barely covered with soil. One of the roots, illustrated separately in Fig. 109, had virtually no mesocotyl, indicating that the kernel from which it grew germinated on the surface of the soil.

One of the specimens still had the main root of the primary or seminal root system. Although broken, this was 95 mm. long and had the stumps of numerous broken secondary roots. The seminal root system, which arises from the radicle of the embryo, is in most modern maize a temporary one, maintaining the seedling only until the permanent root system, which develops adventitiously from the lower nodes of the stalk, begins to function. However, in certain drought-resisting varieties grown by the Indians in the southwestern United States, the primary root system makes an early and rapid penetration into the deeper, moister soils and continues to function throughout the life of the plant (see Collins 1914). Persistence of a primary root system in one of the archaeological specimens indicates that the Tehuacan maize had a similar adaptation to subhumid conditions. This would have been a useful trait in a wild maize growing in this region. A seedling resulting from germination induced by the first rain does not immediately develop its permanent root system if the surface soil has become dry by the time the seedling emerges. It is in a precarious state with respect to its water supply unless its seminal root system can quickly penetrate the deeper moister soils and so main-

Fig. 108. These roots (Palo Blanco phase, San Marcos Cave, actual size) show that the plants had no tillers.

tain the seedling until additional rains moisten the surface of the soil and the permanent root system develops.

Another fact revealed by these five roots is that the plants had single stalks and no tillers, otherwise there would have been visible scars where the tillers had been removed or lost. This discovery is somewhat surprising. Virtually all grasses, wild or cultivated, have the capability of producing tillers. Most grasses are single stemmed only when they are grown under conditions of great stress and are depauperate. Some of the plants of our genetically reconstructed ancestral form tiller profusely. It has generally been assumed that wild corn was a freely tillering plant (Weatherwax 1954; Mangelsdorf 1958*a*). Yet none of the basal stalks from San Marcos Cave or from any of the other caves show the scars indicating that the plants once had tillers.

One more bit of information can be gleaned from these five root specimens. The upper regions of the permanent roots have no secondary roots or scars where secondary roots had once been attached. This shows that they probably were not covered with soil. The practice of hilling—pulling soil around the base of the plant—which is common in Mexico today, had apparently not yet been invented.

San Marcos Cave, Zones C[1] and B

These zones, representing the Palo Blanco phase of about 200 B.C.–A.D. 800, contained an abundance of remains of all parts of the maize plants except the kernels, of which there were only two. The numbers of

Fig. 109. Root (Palo Blanco phase, San Marcos Cave, actual size). Extreme shortness of the mesocotyl indicates that this plant grew from a kernel germinating on the surface of the soil.

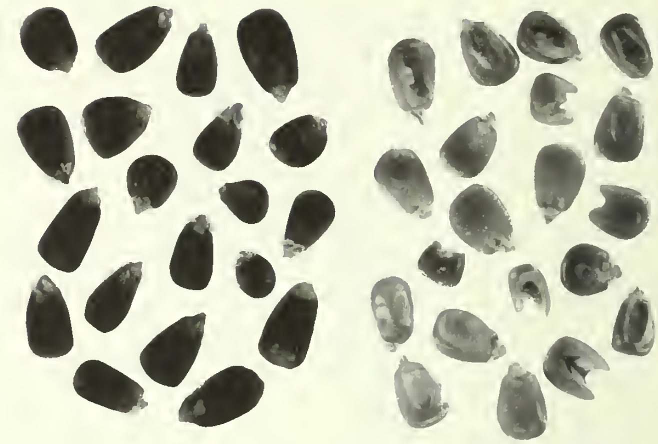

Fig. 110. Kernels of the races Chapalote, *left*, and Nal-Tel, *right*, from the Venta Salada phase of El Riego Cave. Actual size.

specimens of each part identified are shown in Table 21. A brief description of these follows.

Cobs

The introduction of the tripsacoid maize into the Tehuacan Valley and its subsequent hybridization with the wild and early cultivated maize resulted in the production of several new types. The most conspicuous of these is the new race which appears to be the ancestral form of two of the ancient indigenous races of Mexico, Chapalote and Nal-Tel, described by Wellhausen *et al.* 1952. In its brown pericarp color, Chapalote is one of the most distinctive races of Mexico. It is found today in northwestern Mexico, principally in the states of Sinaloa and Sonora. Nal-Tel, which is closely related to Chapalote (Wellhausen *et al.*), differs from it primarily in having an orange-colored pericarp. Nal-Tel also tends to have ears somewhat shorter and with slightly fewer rows than those of Chapalote.

In other characteristics the two races are quite similar and it is not generally possible to distinguish the two by their cobs. For this reason we hoped to find well-preserved kernels to show us with which race we were dealing. In the last of the boxes containing the hundreds of maize fragments from Zone B there were two kernels wrapped in separate small packages. Opening the first, we found a kernel with orange pericarp like Nal-Tel. Opening the second we found a kernel with brown pericarp like Chapalote. We have since encountered both colors in collections from the other caves in Tehuacan Valley. Kernels of the two races from El Riego Cave are illustrated in Fig. 110.

Because we were unable to distinguish the cobs of these two races, we combined them and described them in an earlier article (Mangelsdorf *et al.* 1964) as the Nal-Tel–Chapalote complex. We shall continue to use this term. Further study, however, makes it now seem probable that the original wild corn of the Tehuacan Valley was Chapalote rather than Nal-Tel. One reason for reaching this conclusion is that the majority of early cobs are brownish in color. Earlier we considered this to be the product of aging—old cobs often do turn brown. Later it became evident that even among the well-preserved cobs the lemmas and paleas of some are light and of others are brown. Of the various alleles at the *A* locus on chromosome 3, which is responsible for plant color, two, A^b and a^p, in combination with the *P* locus for pericarp color on chromosome 1, produce brown pericarp and cob colors which are dominant to other colors of these tissues (Emerson *et al.* 1935). Dominant genes are often more common in wild or primitive populations than in highly

Fig. 111. Cobs of the Nal-Tel–Chapalote complex (Palo Blanco phase, San Marcos Cave, actual size).

evolved ones, and in this respect Chapalote may be regarded as more primitive than Nal-Tel. Also the fact that both *Tripsacum* and teosinte have brown pericarps suggests that this may be the "wild" color. The orange color of Nal-Tel may be a mutation which occurred after maize had hybridized with *Tripsacum* or teosinte. We know that the introgression of *Tripsacum* or teosinte into maize had mutagenic effects (Mangelsdorf 1958[b]).

Of 581 cobs in these zones, 133 or 23 percent could be assigned to the Chapalote–Nal-Tel complex (Fig. 111). Eight cobs from Zone C (Ajalpan phase) can now also be included in this complex, as can two cobs from Zone IX (Abejas phase) of Coxcatlan Cave. All of these are very primitive.

The remaining cobs from Zones B and C represent for the most part types previously encountered. The introduced tripsacoid had increased in frequency and now comprised 30 percent of the total cobs. Strongly tripsacoid segregates accounted for another 18 percent. These two types together, now called "early tripsacoid," were the predominating type, accounting for 48 percent of all identified cobs in Zones B and C[1].

Second in importance numerically, accounting for 38 percent of the cobs in Zone C[1], is the type that we call "wild-type segregates" (included in Table 22 under "early cultivated"). These cobs resemble the original wild maize of Zones F, E, and D in size, but the majority have glumes and rachises which are more indurated than those of wild corn. A number are two-ranked and some have single spikelets. Representative specimens of this type are illustrated above in Fig. 106.

One explanation to account for these wild-type segregates is that the introduced tripsacoid corn hybridized not only with cultivated corn but also with wild corn still growing in the valley. The first generation hybrids arising in the wild habitat would then have backcrossed to the wild maize, producing segregating populations containing some individuals which were quite capable of surviving in the wild. Indeed the wild maize may actually have been improved in some respects by the genes for toughness and hardness conferred on it by the tripsacoid maize.

Some of the remaining cobs were classified as intermediate between the introduced tripsacoid and the wild maize. In the frequency polygons in Fig. 123 all of the tripsacoid types have been combined in the category designated as "early tripsacoid."

Beside these more primitive tripsacoid cobs there were 108 cobs that showed tripsacoid introgression with the more modern races (Nal-Tel–Chapalote). These are termed "late tripsacoid" and are very difficult

Fig. 112. Husks (Venta Salada phase, Tecorral Cave, actual size).

to define exactly (see Fig. 120 below). Data on intact cobs from all zones of San Marcos Cave are presented in the accompanying tabulation. The figures for each zone are averages based on the total number of intact cobs from the zone.

Tc 254 zones	*Cobs*	*Length in mm.*	*Rows*	*Spikelets per row*	*Total spikelets*
B	91	55	11.0	14.8	163
C^1	60	47	10.8	12.4	134
C	2	45	10.0	12.0	120
D	10	43	8.3	13.6	113
E–F	8	22	7.3	7.5	55

Husks

There were many fragments of husks in this zone, but only 45 were intact in length. Thirty-six of these were classed as outer husks and nine as inner. The length of the former varied from 70 to 210 mm., with an average of 145 mm. The majority were fairly close to the average. The husks classified as inner varied from 100 to 160 mm., with an average of 135 mm. All of the husks except two were lacking in flag leaves. One of the exceptions had a rudimentary leaf, the other a well-developed leaf that is 100 mm. in length. As mentioned below in the description of leaf sheaths, some of the husks, which actually are modified leaf sheaths, were colored. Husks are shown in Fig. 112 and 113.

Prophylls

"In the branch system of grasses, each lateral shoot has a bikeeled first leaf (prophyll) facing the axillant leaf and addorsed to the main axis" (Arber 1934). This structure, the prophyll, is especially prominent in modern maize where it subtends the ear-bearing branch. By the layman it may be regarded as one of the husks. It differs from the husk, however, in being distinctly bikeeled. Three prophylls were found in Zone B, and as was to be expected, all were bikeeled.

Shanks

The stem subtending the ear and from which the husks arise, in botanical terms a peduncle, is commonly called the shank. On six complete husk enclosures, the diameter of the shanks at the base of the lowermost husk average 8.3 mm., and the distance between the lowermost and uppermost husk varied from 23 to 74 mm., with an average of 36 mm.

Stalks

The total of 43 pieces of stalks were sufficiently well preserved to be measured with respect to diameter. Thirteen of these had remnants of roots and therefore represent the basal internodes. Their average diameter was 11 mm., which is about half that of the Colombian primitive races, Pollo and and Pira, grown under agricultural conditions. The remaining fragments, probably representing a more or less random sample with respect to their original positions on the plant, varied in diameter from 3 to 18 mm., with an average of 7.2 mm. Pieces of stalks are illustrated in Fig. 114.

Leaf Sheaths

Of the 79 leaf sheaths examined, 67 proved to be completely glabrous, and 11 had short hairs in the

grooves between the ridges. One had sparse hairs on the ridges. Actually, to the naked eye as well as to the touch, even the 11 short-haired sheaths appeared glabrous. Thus with respect to hairs or bristles these 79 specimens represent the most uniform lot of sheaths which we have encountered in either archaeological or modern maize. It seems highly improbable that one of the ancient indigenous races of maize of Mexico, Palomero Toluqueño, which has strongly pilose leaf sheaths, could have originated from the populations found in the Tehuacan Valley. This is one of several reasons for supposing that there may have been more than one kind of wild corn.

Practically all of the prehistoric leaf sheaths are brownish or reddish brown in color. We supposed initially that this represented discoloration from aging. Some specimens, however, had a distinct reddish cast and when soaked in hot water imparted a reddish tinge to the water. It now seems probable that the color of these specimens is not mere discoloration from age but represents the remains of natural plant color. As mentioned above, some of the husks were also colored.

Leaves

Numerous fragments of maize leaves were found. The majority were too badly broken to yield much information, but four were intact for both length and width and ten additional ones for width. The intact leaves had an average length of 47.6 cm., and an average width of 4.1 cm. The leaves intact for width varied from 2.7 to 5.0 cm., with an average of 3.8 cm. These dimensions are much smaller than those of any modern races of maize in Mexico—even the ancient indigenous races, which compared to some other races have relatively narrow leaves. Leaves arising from the ear-bearing nodes of Chapalote and Nal-Tel, for example, have average lengths of 80.5 and 65.6 cm. respectively and widths of 7.6 and 8.7 cm. (Wellhausen *et al.* 1952).

The venation index—a measure of the number of veins per unit (cm.) of width—of 17 leaves which were scored for this characteristic varies from 3.8 to 6.7, with an average of 4.5. This is much higher than the venation indices of modern Mexican maize (Wellhausen *et al.* 1952) and puts prehistoric maize in a class with teosinte with respect to this particular characteristic.

Tassel Fragments

Thirty-three tassel branches or fragments of branches were found in this zone. The length of the pedicel on the pedicellate spikelet was measured on one spikelet from each specimen. This varied from 1 to 6 mm.,

Fig. 113. Branched lateral inflorescences (Palo Blanco phase, San Marcos Cave, actual size). Such plants probably bore a cluster of small ears.

Fig. 114. Pieces of stalk (Palo Blanco phase, San Marcos Cave, actual size).

Fig. 115. Tassel (Palo Blanco phase, Coxcatlan Cave) and leaf fragment (Venta Salada phase, Tecorral Cave). Both actual size.

Fig. 116. Tassel fragments (Venta Salada phase, San Marcos Cave, actual size).

averaging 3.7 mm. The lower glumes on these same spikelets varied in length from 7 to 12 mm., averaging 9.2 mm. There was some variation in the shape of the spikelets, the majority being somewhat flat dorsally, giving the impression of a bikeeled structure. This is characteristic of the glumes of some species of *Tripsacum*. Five of the 33 specimens, however, did not exhibit the impression of distinct keels and all of these were shorter than the average and resembled the spikelets in the single fragment found in Zone D and illustrated in Fig. 101. Four of these five tassel fragments differed also from the majority in lacking hairs on the glumes. In size, shape, and hairiness of the glumes, these four specimens resemble the original wild or early cultivated corn.

One of the unique characteristics of maize is the central spike of the tassel which differs from the branches in being polystichous rather than distichous. There have been various theories about the origin of this structure (see Mangelsdorf and Reeves 1939 for a review of this subject). It is interesting to note that the polystichous central spike was characteristic of corn in prehistoric times. The several fragments representing central spikes are illustrated in Fig. 116. An intact tassel including a central spike from Coxcatlan Cave is shown in Fig. 115.

Because our genetically reconstructed ancestral form bore seeds in the branches of the tassel thus providing a means of dispersal which modern corn lacks, we expected to find some evidence of this characteristic in the tassels of the prehistoric Tehuacan corn. In this we were disappointed. Of the 384 specimens of tassels found in the five caves, only one from Coxcatlan Cave (Fig. 115) seemed to be a tassel branch bearing pistillate spikelets at its base. Since depauperate corn plants even of modern corn sometimes exhibit this condition, its rare occurence among the prehistoric specimens is

Fig. 117. Quids (Palo Blanco phase, San Marcos Cave, actual size). Most of these are chewed corn stalks. Lower specimens show how the chewing proceeds along the stem. Actual size.

not especially significant. On the contrary, it is surprising that there are not more of these, since both wild and cultivated corn must at times have been exposed to environmental conditions which were conducive to production of depauperate plants.

Quids

There were in this zone 58 remains of quids, of which 32 were chewed stalks and 26 chewed husks. The latter probably originally contained young ears. We had previously found from trials associated with explaining the quids in La Perra Cave (Mangelsdorf *et al.* 1956) that young ears enclosed in husks are quite sweet. Also it is well known that growing corn stalks from which the ears have been removed, or which are barren for other reasons, often accumulate sugars and are about as sweet as sugar cane—although somewhat less palatable when chewed. Since a "sweet tooth" is almost universal in the human race, it is not surprising to find that the Tehuacan people made use of the sweetness derived by chewing young ears and stalks of corn. Quids in various stages of maceration are shown in Figs. 117 and 118.

Collections from Other Caves

The maize specimens from the remaining four caves (Coxcatlan, Purron, Tecorral, and El Riego) did little more than to corroborate the conclusions drawn from the collection from San Marcos Cave. But they did so very effectively, as perusal of Table 22 will show. Coxcatlan Cave, which was occupied more often and over a longer span than San Marcos, had a large sample totaling over 15,000 specimens. The majority of the earliest specimens from components of the Coxcatlan phase (11 fragments and 6 whole cobs from Zone XIII, 5 whole cobs from Zone XII, and 6 fragments and 6 whole cobs from Zone XI) showed that Coxcatlan Cave's earliest maize has four- and eight-rowed cobs with relatively long glumes and slender rachises. This we assume to be wild corn. However, one cob in Zone XIII and three from Zone XI were somewhat larger in size, and these are presumably the first products of cultivation. In the Abejas levels of Coxcatlan Cave cobs of both wild and early cultivated types occur, but the early cultivated specimens (one cob from Zone X. 11 cobs and 7 fragments from Zone IX, and 7 cobs from Zone VIII) far outnumber the wild ones (7 from Zone IX and 2 from Zone VIII). Also, at this time the first tripsacoid cobs (one cob from Zone X and 6 from Zone VIIII) make their appearance. Two tiny cobs of the Nal-Tel–Chapalote complex were uncovered in Zone IX.

Fig. 118. Quids in various stages of maceration (Palo Blanco phase, San Marcos Cave, actual size).

The Purron phase was meagerly represented in Zones K and K[1] of Purron Cave by three burned cobs of early tripsacoid corn. Zone J of Purron Cave supplemented our larger Ajalpan sample from Zone C of San Marcos. Zone J also showed a dominance of early tripsacoid types (10 cobs) with a lesser number (2 fragments) of early cultivated types.

In the Santa Maria zones of Coxcatlan Cave (Zone VII) and Purron Cave (Zones G, H, and I) there is further evidence of more use of the Nal-Tel–Chapalote complex as well as hybridization of this maize with both wild and cultivated corn to produce new variation on a grand scale (late tripsacoid, Fig. 120).

A New Type: Slender Pop

In the Palo Blanco phase the collections from Coxcatlan, Purron, and El Riego caves do, however, reveal a type of maize which, if it occurred in San Marcos Cave, was not clearly recognized. We have designated this type as "slender pop." The cobs (Fig. 119) are slenderer than those of Chapalote or Nal-Tel and are more nearly cylindrical in shape. Remains of occasional kernels indicate that they were quite small, rounded in shape, and orange in color. This may be the prototype of a Mexican popcorn, Arrocillo Amarillo, one of the four ancient indigenous races described by Wellhausen *et al.* (1952). This race, which is now mixed with many others, occurs in its most nearly pure form in the Mesa Central of Puebla at elevations of 1600–2000 meters, not far from the Tehuacan Valley and at similar altitudes. Another modern race of maize which resembles the prehistoric slender pop even more closely is Pira

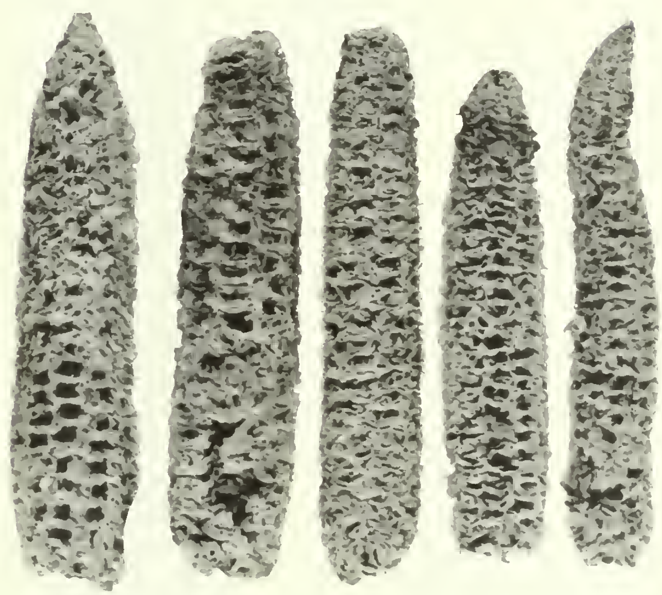

Fig. 119. Cobs of slender pop (Venta Salada phase, Coxcatlan Cave, actual size).

Naranja found in the Department of Nariño in southern Colombia and described by Roberts *et al.* (1957). It is difficult to see how this Colombian race could have had its antecedents in the Tehuacan Valley and have left no trace of its former presence in any areas between these widely separated points in Mexico and Colombia. Perhaps the resemblances are merely coincidental, but perhaps future investigations will show that the prehistoric slender pop of Tehuacan and the orange popcorn of Colombia are in some way related. In any case,

Table 22. Maize Cobs and Kernels by Race

	Wild Maize		Early Cultivated		Early Tripsacoid		Nal-tel and Chapalote		Late Tripsacoid		Zapalote Chico			Slender Pop		Zapalote Grande	Conico		Dent	Tepe-cintle	Chal-queno
	Cob fragments	Whole cobs	Cob fragments	Whole cobs	Cob fragments	Whole cobs	Cob fragments	Whole cobs	Cob fragments	Whole cobs	Kernels	Cob fragments	Whole cobs	Cob fragments	Whole cobs	Whole cobs	Kernels	Whole cobs	Kernels	Kernels	Kernels
Venta Salada																					
Tc 35e, A							67	126	2	232	137		22	16	205				1	5	2
Tc 50, I						22	16	632	28	208				6	121		4				
Tc 50, II						1	46	589	16	349				152	444						
Tc 35e, B							68	143		105		1	4	130	231	1			3		
Tc 50, III						18	1395	1613	96	392				41	107			208			
Tc 255, A				3				7						2	32						
Tc 35e, C					54	16	184	420	134	445				37	409						
Palo Blanco																					
Tc 35e, D							41	130		100					1						
Tc 35e, E					3	2		12		26					1						
Tc 50, IV					13	38	257	553	122	528			2	34	95						
Tc 254, B		1		2		226		123		93			2								
Tc 254, C		5		51		53		10		15											
Tc 50, V						1	130	157	12	286					2						
Tc 272, A							20	84		12				16	31						
Tc 272, B							10	28						16	23						
Tc 272, C							29	73	2	11				2	12						
Tc 272, D				2			20	21	5	6				3	4						
Tc 272, E		4		1			12	92	4	13				5	25						
Tc 50, VI					163	1521	9	159		291			1			1					
Tc 272, F							5	12													
Santa Maria																					
Tc 50, VII	30	37		35	54	268	26	47		73			1		2						
Tc 272, G							14	16													
Tc 272, H							11	1													
Tc 272, I					2	6		2													
Ajalpan																					
Tc 254, C[1]	9	28	7	36		86		8													
Tc 272, J			2			10															
Purron																					
Tc 272, K[1]						1															
Tc 272, K						2															
Abejas																					
Tc 50, VIII		2		7		6															
Tc 50, IX		7	7	11				2													
Tc 254, D	20	38	15	28	1																
Tc 50, X				1		1															
Coxcatlan																					
Tc 50, XI	6	16		3																	
Tc 254, E	5	21																			
Tc 254, F		1																			
Tc 50, XII		5																			
Tc 50, XIII	11	6		1																	

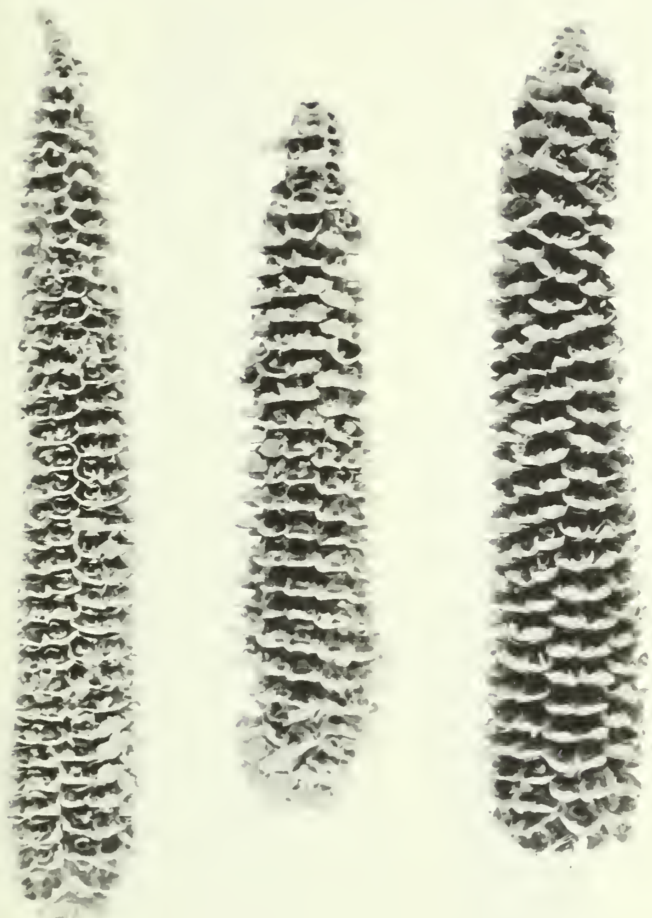

Fig. 120. Cobs of late tripsacoid corn (Venta Salada phase, Coxcatlan Cave, actual size).

the slender pop, which first appeared at the very end of the Santa Maria phase (2 cobs from Zone VIII, Coxcatlan Cave), increased rapidly and steadily in frequency, comprising 21 percent of all cobs of the final phase.

Judged by its cobs alone the slender pop might be expected to be less productive than Chapalote or Nal-Tel. The fact that it increased in prominence suggests that although the ears are small the stalks may have been prolific, bearing more than one ear. The present-day race, Arrocillo Amarillo, to which the slender pop bears some resemblance and to which it may be related, is prolific, usually producing two or three ears per stalk. The maximum yields of corn in the United States are made by prolific types of corn grown under irrigation. Perhaps this was also true in prehistoric Tehuacan.

Cobs of Modern Races

A few cobs which could be assigned to various modern races were found in the upper zones of Coxcatlan and El Riego caves. These included several cobs and kernels resembling the race, Conico (Fig. 121), and one cob each of Zapalote Chico, Tepecintle, and Chalqueño, as well as kernels of an unidentified dent corn. The surprising thing is not that specimens of these modern races were present, but that there were so few of them. These races were certainly in existence in Mexico centuries ago. At least two modern races, Tuxpeño and Olotillo, are recognized in the molds on Zapotec funerary urns dated at about A.D. 600–700. If they were common enough to furnish the motifs for funerary urns in the region now represented by the state of Oaxaca, it seems strange that they did not find their way in any substantial numbers into the agriculture of a region which is now the adjoining state of

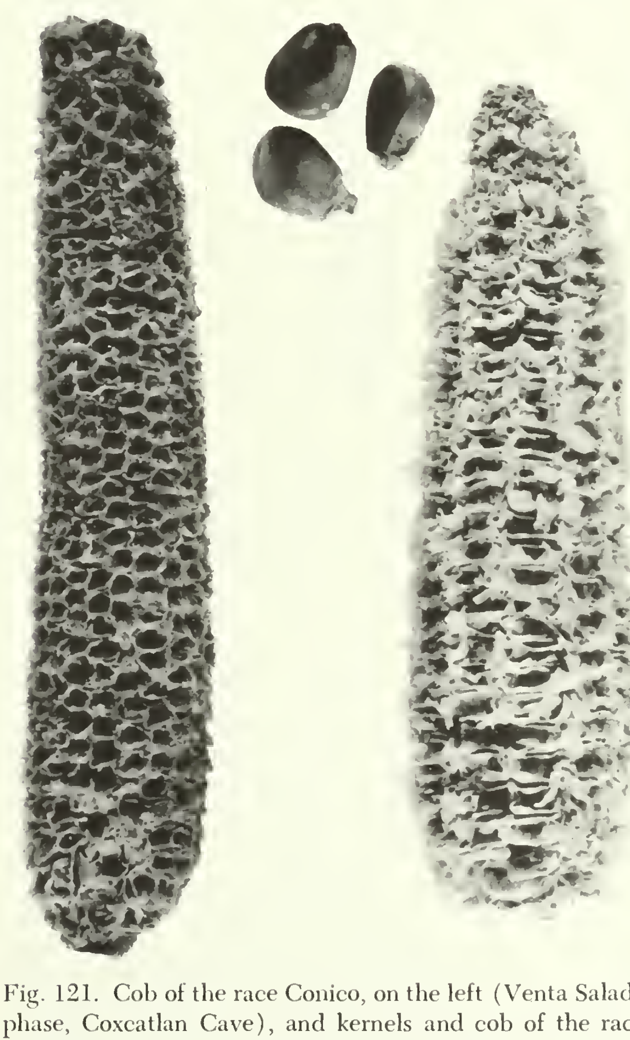

Fig. 121. Cob of the race Conico, on the left (Venta Salada phase, Coxcatlan Cave), and kernels and cob of the race Tepecintle (Venta Salada phase, El Riego Cave). All actual size.

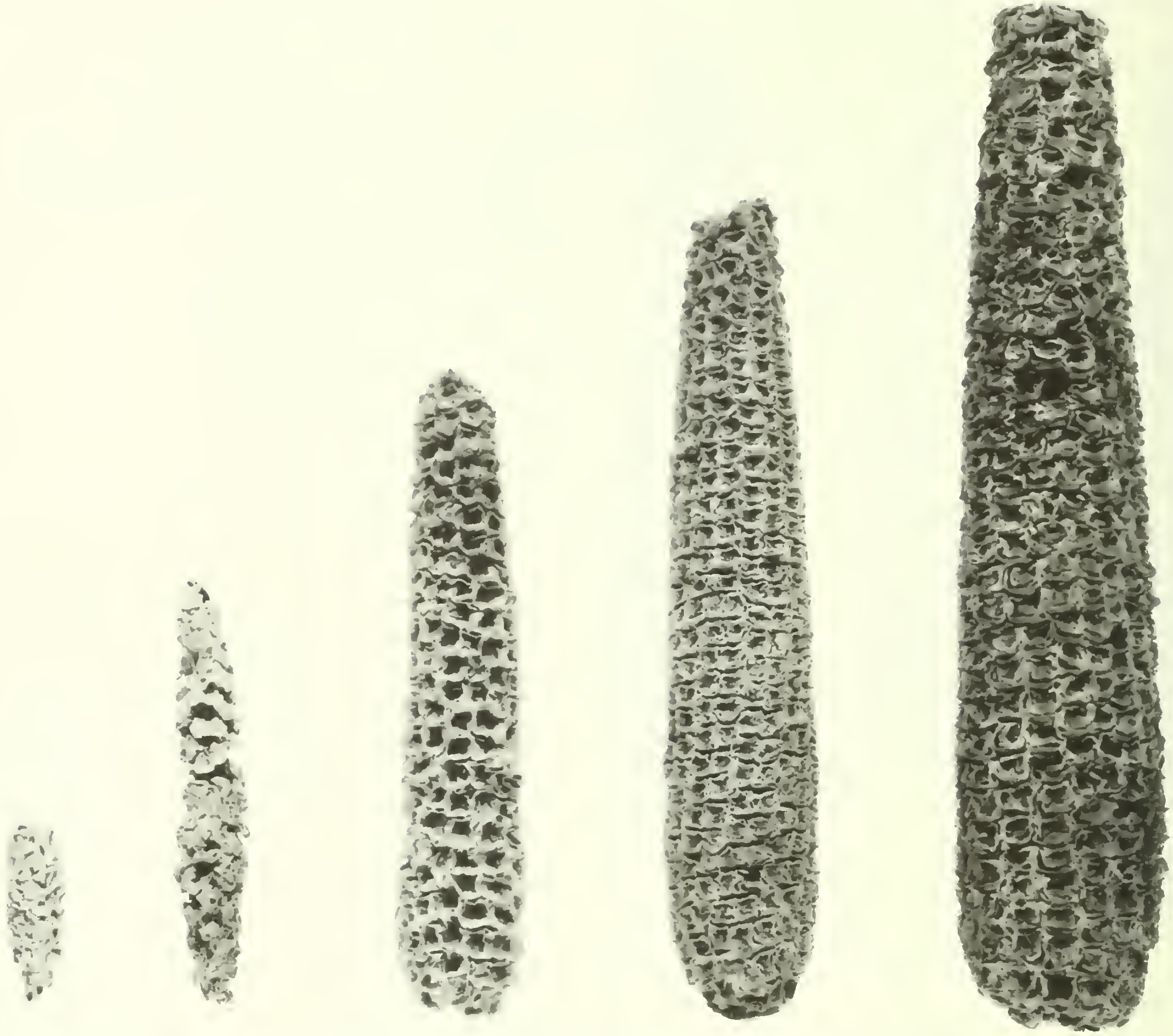

Fig. 122. Cobs (actual size) illustrating an evolutionary sequence from about 5000 B.C. to about A.D. 1500: wild corn, Coxcatlan phase, San Marcos Cave; early cultivated, Abejas phase, San Marcos Cave; Chapalote, Palo Blanco phase, San Marcos Cave; Chapalote, Venta Salada phase, Coxcatlan Cave; Conico, Venta Salada phase, Coxcatlan Cave.

Puebla. Here is one of the numerous minor questions which the prehistoric remains of corn from Tehuacan Valley have raised while answering the much more important major ones. Cobs illustrating an evolutionary sequence are shown in Fig. 122.

The polygons in Fig. 123 show when each of the recognized types of corn made its first appearance, reached its highest frequency, and in the case of the wild and early cultivated corn, disappeared. The boundaries between the categories represented in Fig. 123 are by no means hard and fast. The type called "late tripsacoid," for example, might well be included as part of the Nal-Tel–Chapalote complex. It differs from the latter only in the fact that the cobs are on the average more tripsacoid than those of Chapalote and Nal-Tel. Also some of the cobs are similar to those of the slender pop, but somewhat more tripsacoid. In any case it is these three types, Nal-Tel–Chapalote, late tripsacoid, and slender pop which supported the expanding populations of the Tehuacan Valley from about 900 B. C. to A.D. 1500.

Wild Corn Reconstructed

A well-preserved early cob and an intact husk system consisting of an inner and outer husk from the Abejas phase, together with a piece of staminate spike

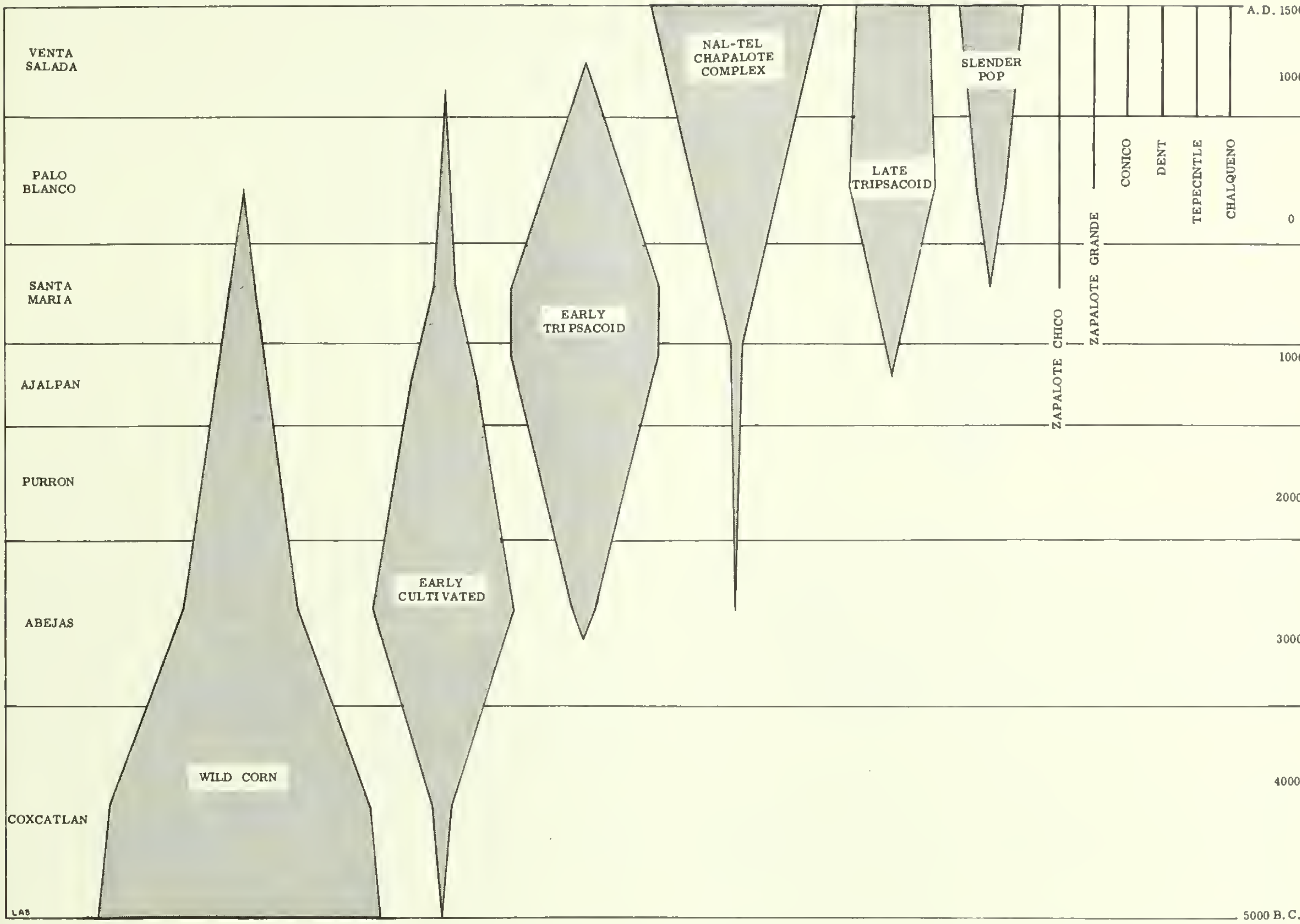

Fig. 123. Changes in types of corn in the Tehuacan Valley, 5000 B.C. to A.D. 1500, in terms of percentages of number of cobs identified. Specimens of corn are almost totally lacking from the Purron phase.

(actually found in the Ajalpan phase), all from San Marcos Cave, provide the material for the reconstruction of an ear of Tehuacan wild corn. This is illustrated in actual size in Fig. 124. An ear with only two husks was probably borne either in high position on the main stalk or in a terminal or near terminal position on a branched lateral inflorescence. In either case the husk would have served primarily to protect the young ear and would have flared open at maturity, permitting the ear to disperse its seeds. The ear, like ears of some modern primitive races, was terminated by a fragile staminate spike bearing spikelets in pairs, one member of each pair pedicellate and the other sessile. The glumes of the staminate spikelets were membranous, glabrous, and lacking in keels.

The wild corn was a form of pod corn. Its seeds were partially but not completely enclosed in floral bracts. These are similar in relative lengths and the extent to which they enclosed the kernels to a genotype which we have produced in our experimental cultures by combining one of the alleles at the tunicate locus, tu^h, on chromosome 4 with a major tunicate modifying gene, *Ti*, on chromosome 6. The terminal inflorescences, the tassels, were similar to those of modern maize in having a polystichous central spike and distichous branches. Apparently they were completely staminate and in this respect differ from our genetically reconstructed ancestral form in which many of the tassels bear both staminate and pistillate spikelets. The kernels, which were borne in pairs, were almost isodiametric in their dimensions, were rounded dorsally, and were either brown or orange in color, probably the former. The specimens from both San Marcos and Coxcatlan Caves show that the plants apparently had single stalks, although they may have had the capacity to produce tillers under especially favorable condi-

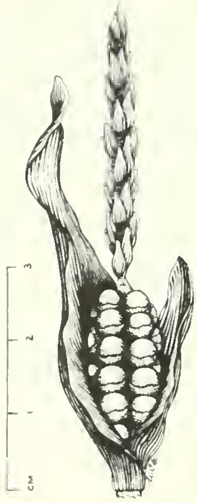

Fig. 124. Wild corn (actual size) reconstructed on basis of a fragment bearing male spikelets and kernels from early levels of San Marcos Cave. The husks probably enclosed the young ears completely but opened at maturity, permitting dispersal of the seeds. The kernels were round, brown or orange, and partly enclosed by glumes.

tions, as do virtually all other wild grasses. The leaf sheaths and husks were completely glabrous and some, if not all, were reddish brown in color. The ear-bearing lateral branch had as its first leaf a bikeeled prophyll. The root system, like that of modern maize, comprised both seminal roots arising from the radicle of the embryo and permanent roots arising from the first and higher nodes of the stalk. The seminal root system, like that of certain drought-resistant varieties grown by the Indians of the American southwest, may have been more extensive and persistent than in most modern varieties.

In all of its essential botanical characteristics, the wild and early cultivated corn of Tehuacan was identical with modern corn but was smaller in all of its parts. Indeed, the wild corn with its tiny ears must initially have been less useful as a food plant than the wild squashes and scarcely more promising than some of the weedy grasses of our gardens and lawns. It was, however, responsive to the improved environment provided by agriculture, and cultivation immediately produced a substantial increase in size. Subsequent hybridization with its relatives, *Tripsacum* or teosinte, initiated an explosive evolution which resulted in tremendous variability and a manyfold increase in size. Despite the spectacular increase in size and productiveness under domestication, which helped make corn the basic food plant of the pre-Columbian cultures and civilizations of America, there has been no substantial change in 7000 years in the fundamental botanical characteristics of the corn plant.

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CHAPTER 10

Archaeological Phaseolus from Tehuacan

Lawrence Kaplan

The genus *Phaseolus* of the legume family comprises about 160 species (Willis 1951). Because of extensive synonymy of recorded species names, particularly among the Old World species in this genus, the actual number is probably considerably smaller. On the basis of Piper's monograph (1926) of the American Phaseolinae, about 80 species are natives of the New World.

Many of the New World species are perennials, with white flowers or, more often, flowers pigmented with red or purple anthocyanins. Yellow flowers are uncommon. Pods of the cultivated species are cylindrical or broad. Many of the Old World species have yellow flowers and all have morphological features of the flowers that contrast with floral structure of the American beans. Six Asian-African species, including the grams, urds, mung, and rice beans, are widely cultivated in Asia and have been introduced elsewhere to a limited extent. These Old World cultivated species are annuals and have small seeds and small cylindrical pods. Differential susceptibility to certain fungus diseases further distinguishes the Old and New World species.

Four cultivated species of New World origin are important as food crops:

P. vulgaris L.—common bean, frijol (derived from a name for the Old World broad bean, *Vicia faba*); etl, yetl (Nahuatl); buul, chenek (Mayan); poroto (Quechua and Aymara). This polymorphic, poorly understood species includes hundreds of cultivated varieties; for example, Navy, Red Kidney, and Pinto beans. *P. vulgaris* and the three species discussed subsequently include strongly to weakly vining forms and bush or erect forms. The distinction between green, string, or snap beans and dry or field beans is based on use rather than on botanical characteristics.

This is the most widely grown of all food beans. In tropical indigenous American agriculture common beans are grown on neutral to slightly alkaline soils from sea level to over 2000 meters elevation.

P. acutifolius Gray, var. *latifolius* Freeman—tepary, escomite. At the present time this bean is not cultivated on a commercial scale, although some field stations have been investigating its potential as a dry-land seed or forage crop. The seeds of this species are smaller than those of other cultivated American beans, but they overlap in size the smaller-seeded common bean varieties. Collections made a few decades ago (deposited in the Museum of Anthropology, University of California, Berkeley) show the tepary to have been common in markets along the Pacific coast of northern Mexico. In 1954 it was infrequent in markets in that region. The disjunct range of this bean—from the Sonoran Desert south through Jalisco and then a gap in its occurrence until the Tapachula–Guatemalan border region—suggests that the present distribution is a relic distribution (Fig. 127).

P. lunatus L.—sieva, small lima, Carolina bean, frijol de haba (in Mexico this may also apply to the introduced broad bean, *Vicia faba*), comba (Guerrero), patashete (Chiapas), guaracara (Venezuela), cubace (Costa Rica). The curved pod and smaller, often flat seed distinguishes the sieva from the lima, *P. lunatus* var. *macrocarpus* Bentham (synonym, *P. limensis* Macf., the big lima, or in Peru, pallar). Any lima bean encountered in Mexico, Central America, or in indigenous agriculture in the southwestern United States is likely to be a sieva bean. In the southeastern United

States this type of bean has been collected among Cherokees and Seminoles. The commercial limas of the United States, such as Fordhook and Henderson, are of the macrocarpus group and are widely grown in gardens and commercially in the humid coastal valleys of California.

The morphologically similar sievas and limas are fully interfertile and produce viable offspring (Mackie 1943). On the basis of the distribution of the wild species and the archaeological evidence, it is now clear that these two groups are not distinct species, but are independent domesticates deriving from geographically separate races or subspecies. Wild *P. lunatus* (R. W. Allard, personal communication) ranges from Mexico to northern South America and exhibits differences separating the domesticated groups. Archaeologically, the geographic separation of sievas and limas attests to independent domestication. The lima is present in preceramic, preagricultural times (5200 years before the present; collections from Chilca, Peru, by Dr. Frederic Engel) and continue into later times on the north coast of Peru. The Peruvian lima is absent from the archaeology of Mesoamerica. The sieva, with the exception of a few pods of problematic identity in later agricultural (Cupisnique) times, is absent from Peruvian sites.

P. coccineus L.—runner beans, ayecote (Nahuatl derivation); botil (Chiapas); patol, pató (northern Mexico). The most common variety in the United States is the large-seeded Scarlet Runner, sometimes listed in seed catalogues as an ornamental with edible seeds. Seeds of most runner varieties are larger than those of sievas and common beans and are usually purple or variegated purple, although there are white-seeded varieties. The flowers of the purple-seeded varieties are strikingly red; those of the white-seeded kinds are white.

Cultivation of indigenous runner beans is most highly developed in the cool humid uplands of Chiapas and Guatemala, in oak- and pine-forested regions above 1800 meters. In these areas the cultivars and their abundant wild relatives are perennials. Sprouts from the tuberous roots often take over maize fields for the first year or two of the fallowing period. The strongly vining runner beans are interplanted with maize in some fields and in plots adjacent to houses. In home gardens they are treated as herbaceous perennials with a life-span of two to several years. In Madeira (Lowe 1868) the roots persist for seven years and are regarded as poisonous. Tubers of the branching root system in Chiapas may be taken up from time to time, boiled, and eaten. The cooking water is said to be discarded.

Runner beans are cultivated to a more limited extent in the northern Mexican states of the Central Plateau, and according to Bukasov (1930), in Costa Rica, Panama, and Colombia.

Nutrition and Domestication

The principal economic significance of *Phaseolus* beans has probably always been as sources of vegetable protein in the form of dry seeds. Several species, particularly *P. vulgaris*, supply edible immature pods and seeds—that is, snap beans—but because of their high water content at this stage (about 89 percent; Block and Weiss 1956), they do not function as an important dietary protein. On a dry-weight basis, the protein content of the immature pods and beans together totals about 10 percent (Chatfield and Adams 1940), or not quite half that of dry mature seeds, whose protein content is 22 percent (Block and Weiss 1956).

The close relationship between beans and corn in the indigenous diet of the populous cultures of Mesoamerica and the Andean region is, like other traditional dietary combinations, no accident. Quantitative chemical analysis (Jones *et al.* 1938) of corn and beans of contemporary Yucatan Indians have shown complementation in the amino acids of zein, the principal corn protein, and *a* and *b* globulins of the black beans (*P. vulgaris*) that with the corn form the mainstay of the diet. Later studies cited by Block and Weiss (1956) and Albanese (1959) indicate that where zein is the protein in the diet of a monogastric animal, lysine is the amino acid that is limiting and must be made up from another source. Beans, with their relatively high lysine content, supply this amino acid that is deficient in the main food crop, corn, with the result that a dietary protein of high biological value is achieved. It may be noted, however, that while this protein appears to be adequate for some members of the population, such as working males, it is inadequate for the more protein-sensitive members such as lactating mothers and recently weaned children (Altschul 1962).

Beans of different varieties and even of different *Phaseolus* species are high in lysine and tryptophane. Corn varies considerably in total protein but is always deficient in lysine and tryptophane (Block and Weiss 1956). Because amino acid complementation exists in combinations of many corn varieties and bean species and varieties, a kind of universal flexibility in adaptation of these dietary components to human requirements resulted. It is now clear that corn and beans in

some areas—for example, Tamaulipas (Kaplan and MacNeish 1960) and coastal Peru (Towle 1961)—were not domesticated simultaneously nor did they necessarily diffuse together. Wherever these two food crops met, an immediate adaptive combination favored by human selection was formed.

The evolution of human diet is marked by synergistic combinations perhaps to a greater extent than by small increments in the food value of individual nutrient sources. Corn could presumably be selected for increments in total protein. However, because the nutritional insufficiency of plant-seed proteins is the result of limiting amino acids rather than low total protein content, raising the total protein content would not make it much more effective in the diet. The answer to the problem of lysine as a limiting amino acid in corn in indigenous America has been the supplementation of corn with beans, rather than changes in the total proteins or in the array of amino acids of corn.

How did such a useful combination come about? Sampling of the available flora is probably the only answer to this question. Seasonality, yield, compatability with other crops and ways of human life were factors, as well as the nutrients, in determining the adoption of supplementary crops. Sampling of the flora over a period of many thousands of years prior to the establishment of corn-and-bean agriculture roughly 6000 years ago in Middle America—and possibly in the Tehuacan Valley itself, if beans were domesticated there—was evidently sufficient to establish this combination. Given sufficient time, a comparable flora, and similar human practices, the same plants would probably be domesticated.

In some regions having different floras—in, say, the Great Basin of the western United States or the humid eastern United States—indigenous plants do not appear to have been brought under cultivation to the extent that corn and beans were in Mesoamerica. Why does domestication take place in some areas but not in others? Further archaeological and botanical evidence of the sort emerging from Tehuacan should enable groups of scientists to weigh the roles of time and the sequence of human culture, climates, and floras of the past in approaching this question.

Ethnohistory

There seem to be no direct ethnohistorical sources relating to the use of beans in the Tehuacan Valley. Because the paucity of beans in relation to corn remains in some pre-Columbian sites, including some of the Tehuacan caves, tends to give an erroneous notion of the extent of their use, ethnohistorical data from the Valley of Mexico is presented here.

A major source of information on pre-Hispanic tributes is the Codex Mendocino or Codex Mendoza (Cooper Clark 1938), a manuscript based upon older sources and prepared at the direction of the Viceroy Antonio de Mendoza, who served in New Spain from 1535 to 1550. The second part of the codex is made up of tribute lists from settlements subject to Moctezuma II, the last Aztec emperor. A total of 371 towns were required to make regular contributions of corn, beans, and other foods, raw materials, and manufactured items. The symbols for maize and beans in the codex are "troxes" or bins shown filled with corn kernels, beans, and other small seeds, or mixtures of these. James Cooper Clark, editor and translator of the codex, says that "the troxe was a large 10 foot high chest of woven oziers and plastered inside with mortar. The etl or bean can easily be recognized as the black variety with the white eye commonly cultivated in Central America and Mexico" (1938: p. 56). A total annual tribute of twenty-eight bins of corn and twenty-one bins of beans was exacted. Each bin is estimated by Clark to represent 8,000 bushels.

Beans were evidently being grown in huge quantities in central Mexico at this time. Yet in Tehuacan during the late pre-Hispanic Venta Salada period, beans are present only in the same two caves, El Riego and Coxcatlan, in which they had been found in earlier levels.

Structural Changes

Although the domesticated beans differ in several ways from the wild species, the fact that generally only pods and seeds appear in the archaeological remains limits the possible record of change through time to certain anatomical features. One of these is seed size. Seeds of the cultivated taxa vary greatly in size, but they are always larger than the seeds of the most closely allied wild species. Increased seed size can be determined directly from the seeds or indirectly from remains of pods. It constitutes the clearest evidence that a given seed is from a domesticated rather than from a wild plant. All of the archaeological beans that have been studied are domesticates. Wild bean seeds have not yet been reported in archaeological remains nor have transitional phases in size increase been detected.

The early pod remains of *P. vulgaris* at Ocampo in Tamaulipas and in the Tehuacan caves contained seeds within the size range of moderately large commercial beans. The earliest teparies at Tehuacan and

the earliest limas from Huaca Prieta in Peru are not outside the size range of later prehistoric or contemporary cultivars of the same species. Thus, from times of incipient agriculture when remains of *P. vulgaris*, *P. acutifolius*, and Peruvian *P. lunatus* first appear, no significant size changes have occurred. The archaeological evidence clearly demonstrates that transition in seed size took place in times earlier than the earliest archaeological records of beans—that is, during early incipient agriculture or even during pre-agricultural times.

Any conclusions regarding the cultural context of this transition or the selective conditions under which it occurred must be speculative and tentative at best.

The association of corn and beans at Tehuacan some 6000 years ago suggests that the transition in seed size may have come about among beans that were interplanted with corn. Large seeds, by providing an abundant energy reserve for young bean vines, enabled them to survive better in competition for light with the young rapidly growing corn.

Another important feature of seeds that may be affected by domestication is permeability to water. "Hard-seed," an agronomically important and undesirable trait, denotes the inability of the seeds to imbibe water. When a substantial proportion of seeds designated for planting are impermeable to water, the result is uneven germination, with the soft or permeable seeds imbibing water and germinating promptly and the hard seeds exhibiting a delay in the start of growth.

This trait is determined by characteristics of the seed coat which are genetically and environmentally affected. Different varieties of beans may differ greatly in the permeability of their seeds to water. Some cultivated varieties have very low frequencies of hard seeds; others, such as runner beans from Cholula, Mexico, produce seeds of which 50 percent fail to absorb water after 48 hours of immersion at room temperature. Seeds derived from wild species of the genus *Phaseolus* are invariably impermeable. The contrasting permeability of seeds derived from domesticated and nondomesticated species suggest that seed permeability has increased under domestication.

The widespread practice in Mexico of boiling beans without preliminary soaking may reflect the high incidence of impermeability in the local culivated varieties. Imbibing of a seed lot of varying permeability followed by boiling produces an unevenly cooked pot of beans, whereas boiling of dry seed reduces the differences in cooking time between permeable and impermeable seeds. The latter method may produce a uniformly palatable pot of beans, but some protein value may be lost since heating of relatively dry protein and carbohydrate mixtures causes the formation of indigestible protein-carbohydrate complexes (Ellis 1959). Preparation of dry seeds by roasting and grinding, as in the production of pinoles made from wild grasses, maize, or beans (Kaplan 1956), is probably even more detrimental nutritionally.

Seed dissemination is another plant characteristic that may change under cultivation. Economic annual plants grown for their seeds or grains, chiefly legumes and cereals, have usually undergone a reduction or loss of the ability to release their seeds. Wild beans have pods that open along both sutures and forcibly expel their seeds by a twisting of the pod valves that results from desiccation of the inner parchment tissue of the pod. This process of expulsion takes place violently among wild species but less so or not at all among cultivated varieties, owing to a reduction of the parchment layer among domesticates.

The oldest *P. vulgaris* materials, the pods from Tamaulipas and Tehuacan, have reduced parchment layers and for this reason, as well as that of their size, are considered to be derived from domesticates. However, the oldest *P. coccineus* pods from Tamaulipas (Kaplan and MacNeish 1960) are tightly curling wild types.

Table 23. Bean Remains from All Sites by Zone and Phase

	Coxcatlan	Abejas	Santa Maria	Palo Blanco					Venta Salada				
	Tc 50, XI	Tc 50, VIII	Tc 50, VII	Tc 50, VI	Tc 50, V	Tc 50, IV	Tc 35e, E	Tc 35e, D	Tc 35e, C	Tc 50, III	Tc 35e, B	Tc 35e, A	Totals
P. vulgaris													
Pods	1	1		1	1			1	3		3	3	14
Seed, var. 1					1	1	2	108	2	3	183	38	338
Seed, var. 11									149		10		159
Seed, var. 13									2				2
Canavalia sp.													
Seed		1											1
P. acutifolius													
Seed, var. 7		118		485									603
P. coccineus													
Pod				1									1
Seed, var. 9									6	1			7
Seed, var. 12			1									24	25
P. lunatus													
Pods										1		1	2
Seed, var. 8									1			1	2
Totals	1	120	1	487	2	1	2	109	163	4	176	67	1,153

Perennialism is more prevalent in *Phaseolus* than is annualism and is based on drought resistance of the tuberous root or root and basal portion of the stem. Probably about 90 percent of the American species are perennials. *P. vulgaris* and *P. acutifolius* are known only as annuals with fibrous root systems. Some cultivated varieties of *P. lunatus* and *P. coccineus* are tuber-forming perennials in the tropics. Although annualism is a feature characteristic of the cultivated species, there is insufficient evidence to indicate whether this trait arose under domestication or long prior to the advent of human selection.

Impermeability of seeds functions, ecologically, as a dry-season dormancy mechanism just as does the tuberous root. The tuberous root and wild-type seed can probably be considered as ecological equivalents. Because tuber-formation and seed impermeability are reduced among cultivated varieties, an ecological distinction may be added to the morphological distinctions between the wild and domesticated groups. These reductions in dormancy mechanisms geared to the wet-season, dry-season cycle have resulted in a crop plant that is flexible in adapting to new climatic regimes, home-garden cultivation, or to irrigation.

The Tehuacan Remains

P. vulgaris

Although the occurrence of single pods of a cultivated variety of this species in the Coxcatlan and Abejas phases of the Tehuacan sequence demonstrates that common beans were known at periods when agriculture was still subordinate to plant-collecting, common beans do not become abundant until Palo Blanco times. The earliest pod of *P. vulgaris* was recovered from Zone XI of Coxcatlan Cave, which dates to almost 6000 years ago. The earliest date (4300–6000 B.P.) for the presence of pods of *P. vulgaris* cultivars in Tamaulipas (Kaplan and MacNeish 1960) is about the same as that for the Tehuacan Valley. In Tamaulipas as in Tehuacan, common beans, although present in the excavated remains, did not become abundant until agriculture replaced plant-collecting as the chief food source. In Tamaulipas this transition took place in the Palmillas phase 1100–1800 years ago. The history of common beans in Tamaulipas resembles the history of common beans in Tehuacan both in absolute time and in cultural sequence.

A similar sequential pattern, if absolute dates are moved up and time spans compressed, can be discerned in the Southwest of the United States (Kaplan 1956). At Tularosa Cave in western New Mexico and in the San Juan and northern Arizona regions, common beans were present 2000 years ago, but they did not become abundant until 800 years ago. In the Southwest beans are abundant in the remains of cultures in which pottery was utilized and agriculture was the main food source.

P. coccineus

The earliest runner bean specimen from Tehuacan is a single seed from Zone VII of Coxcatlan Cave, a level which represents the Santa Maria phase of over 2000 years ago. A single runner bean pod from a Palo Blanco component of the same cave was the only specimen representing that phase. A number of seeds were found in Venta Salada levels of El Riego Cave, East Niche, and one seed came from a Venta Salada level of Coxcatlan Cave.

The runner bean seeds found in Coxcatlan and El Riego caves were probably not grown in the immediate vicinity of either cave. Conditions in both places are too arid and hot for this cultigen of cool, pine-and-oak-forested uplands. Cultivation of this species was not noted in a brief reconnoiter of the Sierra de Zongolica above Coxcatlan Cave, but a probably related adventive species is present in road cuts and other places where the soil has been disturbed. The vegetation indicates that good crops of runner beans could be raised in these mountains.

The late occurrence of runner beans in Tehuacan suggests that the highlands above Tehuacan are not a region of early domestication of this species. Because runner beans thrive under humid conditions that are not favorable to the preservation of vegetal remains in archaeological sites, a search for early runner beans might well be conducted in arid sites adjacent to a humid upland in central or southern Mexico or Guatemala.

Runner beans today are a common product of the Indian highlands and are traded to towns in the central depression of Chiapas (field notes, 1957). Evidently they were an item of prehistoric highland-lowland transport in the Tehuacan Valley as well.

P. lunatus

The appearance of the few sieva beans recovered from Venta Salada levels of the Tehuacan sites coincides with the growth in importance of common beans. Their appearance in levels dating to about 1000 years ago corresponds with the earliest occurrence of the scanty sieva remains of the Ocampo, Tamaulipas, caves, where a few pods are present in the Palmillas phase (1100–1800 B.P.) and subsequent phases. Dr. G. Willys Andrews, excavating at Dzibilchaltun, near

Fig. 125. Occurrences of four kinds of bean at archaeological sites in the New World, dated in years B.P. Sources: Basketmaker II, Kaplan 1956; Chilca, correspondence of F. Engel; Durango, Carlson 1963; Dzibilchaltun, correspondence of G. Willys Andrews; Fort Ancient, Yarnell 1964; Huaca Prieta, Towle 1961; Nazca, Towle 1961; Ocampo, Kaplan and MacNeish 1960; Oneota and Owasco, Yarnell 1964; Rio Zape, Brooks *et al.* 1962; Snaketown, Tularosa Cave, Verde Valley, Kaplan 1956.

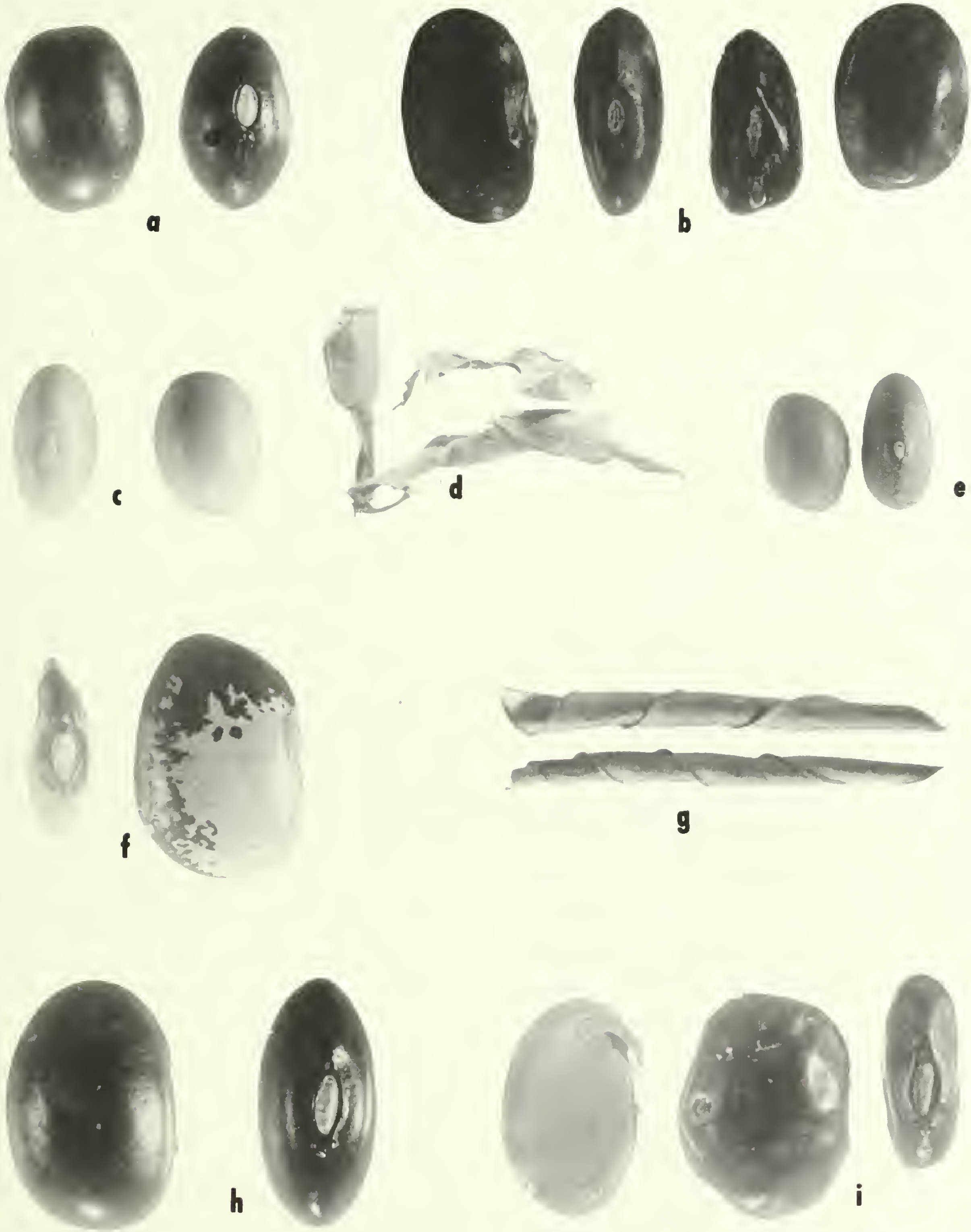

Fig. 126. Beans from the Tehuacan Valley. *Phaseolus vulgaris: a*, Tehuacan 1, Tc 35e, Zone B; *b*, Tehuacan 11, Tc 50, Zone VI; *c*, Tehuacan 13, Tc 35e, Zone C; *d*, pod, Tc 50, Zone VIII. *P. acutifolius* var. *latifolius: e*, Tehuacan 7, Tc 50, Zone VIII. *P. lunatus: f*, Tehuacan 8, Tc 50, Zone VII; *g*, pod, Tc 50, Zone III. *P. coccineus: h*, Tehuacan 12, Tc 50, Zone III; *i*, Tehuacan 9, Tc 35e, Zone C.

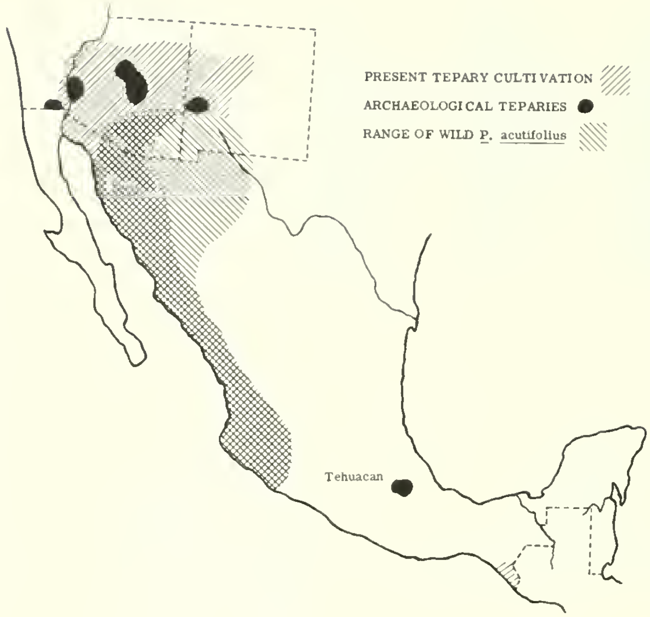

Fig. 127. Distribution of tepary beans.

Merida in Yucatan, recently found abundant charred seeds that I have identified as sieva beans. These beans date to about 1200–1400 years ago. Earlier beans from this site (2270 ± 80 B.P., correspondence from Dr. Andrews) are *Canavalia ensiformis*. The earliest sievas from the southwestern United States grew in the Verde Valley about 1000 years ago (Kaplan 1956). Carter (1951) has noted a protohistoric record probably referring to sieva beans in the eastern United States.

The evidence provided by the widely distributed Mesoamerican sites, each excavated with due regard for the preservation of vegetal remains, suggests the entry of domesticated sieva beans into Mexico sometime between 1000 and 1400 years ago. Taken with this evidence, the absence of sievas in the Rio Zape cave in Durango suggests the possibility of an introduction to Mexico by way of the Gulf coast. The lack of archaeological vegetal materials from the dry coastal and lowland regions of Guerrero and Oaxaca, however, precludes the formation of anything more than an impression in this regard.

P. acutifolius var. *latifolius*

The earliest tepary beans from Tehuacan were a batch of 118 recovered from Zone VIII of Coxcatlan Cave. This level dates from the Abejas phase of roughly 5000 years ago. Another, much larger quantity of teparies came from a Palo Blanco level of Coxcatlan Cave.

The identification (based on anatomic characters described in a manuscript in preparation) of tepary beans among the Tehuacan remains casts a new light on the problem of the origin of this cultigen. Since Freeman's recognition (1912) of the botanical distinction between teparies and common beans there has been considerable discussion of the origin of the tepary.

The earliest tepary beans of reliable date in the Southwest were found in a Basketmaker III site, A.D. 742, near Durango, Colorado (Carlson 1963). There were no tepary remains in earlier caves in the Anasazi area, dating from Basketmaker II times (Kidder and Guernsey 1919), nor were teparies found in late Cochise sites of more than 2000 years ago (Martin *et al.* 1952). Thus it appears that the early inhabitants of the Southwest did not domesticate tepary beans themselves but probably received the domesticated plants from another area.

In the sense used here, domestication means a greater increase in seed size than could be expected from selection without genetic change. The earliest teparies from Coxcatlan Cave have already passed through this stage of domestication. The seeds are more than twice the size of those of wild teparies. Other micro-evolutionary changes are involved in the transition from wild to cultivated beans, but most of these cannot be discerned in the seeds and pods of archaeological specimens. There is no direct evidence that increase in seed size was an adaptive change, but because the formation of large seeds requires a greater energy input than does the formation of small seeds, it is likely that some advantage accrues where relative seed size increases. Because tepary beans first appear during Abejas times, selective pressures toward increased seed size must be referrable to conditions that prevailed then—that is, conditions arising from subsistence based on food-collecting and incipient agriculture (MacNeish 1962).

The use of wild green pods for food may be very old; however, no mechanism by which this mode of use would select for large seed size is apparent. The selective propagation of large-seeded variants required selection for such variants. A comparison of seed dimensions of cultivated and noncultivated *Phaseolus* reveals that the increase in seed size has been disproportionate in favor of cotyledon size. The reserve food supply of the seeds has increased more rapidly than has the growing part of the embryo. Stored food in the seeds of vining plants such as beans enables the young plants to grow through a shadowing screen of covering plants before their leaves reach full sunlight.

Small increments in seed size are not likely to be favored or differentially propagated by pre-agricultural

Table 24. Characteristics of Remains of Phaseolus

	No. of seeds	Median dimensions (cm.) length	width	thickness	Color*	Comments
P. vulgaris						
Variety 1	337	1.2	0.7	0.66	Moderate reddish brown, varies from 10R 3/4 to 2.5YR 3/3. Some seeds with dark longitudinal stripes.	Resembles **bolitas** varieties; widely distributed in contemporary indigenous agriculture in Mexico and southwestern U.S.; present in Mesa Verde, Colo. in Pueblo III times. (Variety 1 hilum averages 0.2 long, 0.15 wide.)
Variety 11	159	1.1-1.5	0.6-1.0	0.4-0.7	Mixed. Black; strong brown 5YR 4/5; moderate reddish brown 10R 3/4; brownish orange 5YR 5/8.	Components of this mixture are sufficiently distinct that each might be ranked as a cultivar. However, the same mixture is still grown and can be purchased in the Ajalpan market.
Variety 13	2	0.8	0.6	0.5	Pale orange-yellow 7.5YR 9/4.	Similar to Southwest type C9 found at Tularosa Cave (Kaplan 1956).
P. acutifolius var. latifolius						
Variety 7	603	0.8	0.6	0.4	Very dark red-brown to brownish orange 5YR 5/8. Darkened by heating.	Teparies having this form but usually white in color have been common in markets of the Pacific slopes of the western mountains of Mexico, among the Hopi, Zuni, and Colorado River tribes, and, archaeologically, in the Verde Valley of Arizona.
P. coccineus						
Variety 9	7	1.2	1.0	0.6	Very dark purple, appear black.	Occurs in highlands of central and southern Mexico; smaller than most indigenous runner beans. New to archaeology. (Variety 9 hilum averages 0.4 long, 0.2 wide.)
Variety 12	25	1.5	1.0	0.7	Moderate red brown 7.5R 3/6 to dark red 2.5R 3/7.	Resembles some of the contemporary **botiles** of Chiapas.
P. lunatus						
Variety 8	2	1.2	0.9	0.4	Very dark mottle on moderate orange-yellow 7.5YR 8/8.	Resembles widely grown commercial cultivar, Florida Speckled Butter. New to archaeology.

*Ref. Nickerson color fan, Anon. 1957.

seed collection. Furthermore, parching, which was probably the predominant preceramic method of preparation for eating (Kaplan 1956), may be more effective when applied to small seeds than to large ones. The refuse heap, however much a garden spot of candidates for domestication, is not an automatic domesticator. It is merely a reservoir of genetic material for selection. In the disturbed, sunny, fertile conditions of the refuse heap, small increments in seed size would have no adaptive value.

However, an environment that places a premium on the ability to survive shaded conditions during the early post-germination phase and that repeats its requirements generation after generation is one that would favor an increase in seed size. Maize plantings during the period of incipient agriculture would have provided such an environment. The fidelity of the maize-bean association in Mesoamerica attests to its antiquity in some regions. If being planted with maize —or even adventive growth in maize plantings—did supply the competitive environment in which beans developed large seeds, then the determinate growth form must have come later and not necessarily in the same region in which the transition in seed size took place.

Maize first appears in the Tehuacan sequence about 6500 years ago (see Chapter 9). About 1500 years later, domesticated teparies appear. Over a succeeding period of nearly 3000 years in the archaeological record, these teparies remained stable in seed size, which is within the range of teparies cultivated at the present time. If domestication of teparies took place in the Tehuacan Valley under the circumstances suggested here, the transition in seed size began with the initial cultivation of maize some 6500 years ago and was completed 1500 years later. This beginning date is at least 2000 years prior to the earliest record of maize in the Southwest.

The principal difficulty in designating the Tehuacan Valley as the center, or even as one of many centers, of domestication of the tepary bean lies in the phytogeography of the putative wild ancestor (see Fig. 127). The nearest collection records for *P. acutifolius* are one thousand miles away in the Jaliscan vegetation area. Records for *P. acutifolius* var. *latifolius*, believed by Freeman to have been the immediate ancestor of the cultivated tepary, are in the northern part of the species range (Piper 1926). Smith (Chapter 12) reports no wild *Phaseolus* species from the Tehuacan Valley and indicates that a comparison of the archaeological and

present xeric vegetation reveals no appreciable climatic changes.

However, an obvious factor in bringing about changes in vegetation during the historic period is the enormous domestic goat population. Their numbers in the Tehuacan Valley, and in other highland valleys of central Mexico, are astonishing, and their pressure on the vegetation is tremendous. To think of the drastic reduction in range of a plant that is without spines or other deterrent to browsing flocks hardly challenges the imagination.

The suggestion that goats have brought about the extinction of the wild ancestor of the domesticated tepary in the Tehuacan Valley, however, does not bear directly upon the question of the identity of the wild ancestor. Although the geographic origin of the tepary has been much discussed (Carter 1945), Freeman's proposal as to the botanical origin of the tepary has not been questioned. If teparies did, as the evidence presented here suggests, pass through the domesticative phase of increased seed size in the Tehuacan region, then the relationship of the tepary to the wild, broad-leafed *P. acutifolius* var. *latifolius* of the Southwest should be seriously examined.

Contemporary Beans

Beans sold in the markets of Tehuacan and Ajalpan were collected in August 1962 to determine the extent to which contemporary varieties resemble prehistoric varieties. Sieva beans, runner beans, and teparies were not available in the markets. In some regions sieva beans are grown for household consumption, but they seldom reach the market stalls.

Five varieties of locally grown common beans were collected. These are all non-vining types grown without irrigation in the hills or surrounding mountains. Beans grown in the valley itself are planted on the plowed mesa tops, like that above El Riego Cave. These too are bush types and are not irrigated. The mesa tops were probably used at one time for teparies, which were replaced by newer introductions of common beans.

One of the common bean varieties grown in the hills above Coxcatlan is identical in seed characters with Tehuacan variety 11 (see Fig. 126 and Table 24). Tehuacan 11 and its contemporary counterpart are similar with respect to the ratio of dark-colored to light-colored seeds. The actual colors are not identical, but because color changes with time, one would not expect them to be. The form and dimensions of the seed are similar, as are characteristics of the hilum of scar of attachment.

Summary

A total of 1,136 bean seeds and 17 pod fragments from Coxcatlan and El Riego caves have been identified and analyzed. Coxcatlan Cave is the only archaeological site on record in which the four principal cultivated American bean species have been found. These species are listed here with the number of varieties present and the earliest estimated date for the species: *P. vulgaris* (common beans), 3 cultivars, 6000 B.P. ± 200; *P. coccineus* (runner beans), 2 cultivars, *ca.* 2200 B.P.; *P. acutifolius* var. *latifolius* (teparies), 1 cultivar, 5000 B.P. ± 200; *P. lunatus* (sieva beans), 1 cultivar, 500 B.P. ± 100.

Beans as a group are represented in the cave remains over a span of about 6000 years, from the Coxcatlan phase to the surface levels which correspond approximately with the Spanish conquest. Although present in the Coxcatlan phase, beans did not become abundant in the remains until about 1000 years ago in Palo Blanco times. The appearance of common, runner, and sieva beans is not earlier respectively than the appearance of these species in northwestern and northeastern Mexico. Data are lacking for other areas in Mexico. The common bean pod from Zone XI of Coxcatlan Cave is about 4000 years earlier than common beans in the southwestern United States.

Common bean varieties represented by the remains from Tehuacan may have been introduced into the region, or they may have been domesticated there. The beans themselves provide no strong evidence either way. Runner beans were probably not grown in the valley, and sieva beans were undoubtedly introduced.

The finding of teparies at Tehuacan extends the range of these beans a thousand miles east of the previously known range of tepary cultivation. The Chiapas–western Mexico–Sonoran distribution of cultivated teparies can now be thought of as a relic distribution. The Tehuacan teparies are about 4000 years older than the earliest archaeological teparies of the Sonoran Desert region. They appear in the Tehuacan record about 1500 years after the earliest maize. The transition from small wild-type seeds to larger seeds characteristic of tepary domesticates could have taken place in the Tehuacan Valley in conjunction with the domestication of maize.

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CHAPTER 11

Cucurbits from the Tehuacan Caves

Hugh C. Cutler and Thomas W. Whitaker

The remains of both wild and cultivated species of cucurbits (gourds, squash, and pumpkins) record in some measure the history of agriculture and the development and movement of cultures in the New World. Although cucurbit material from archaeological excavations is not as abundant as remains of maize, it has four distinct advantages for study over the latter: first, species, and often subspecific groups, can usually be identified reliably from seeds or peduncles (fruit stems); second, the five cultivated species of squashes and pumpkins do not hybridize readily among themselves, as do practically all races of maize; third, specimens of cucurbits from many dated sites are available for comparison; and finally, pre-Columbian distribution of the cultivated species is known with reasonable accuracy (Cutler and Whitaker 1961).

The common terms "pumpkin," "squash," and "gourd" are of little value in distinguishing species of *Cucurbita*. The common New England pumpkin, White Bush Scallop squash, Zucchini squash, Summer Crookneck squash, and Acorn squash, for instance, are all cultivars of the same species, *C. pepo* L., whereas Kentucky Field pumpkin and Butternut squash are cultivars of *C. moschata* Poir. The word "gourd" usually refers to the bottle gourd, *Lagenaria siceraria* (Mol.) Standl. Several tropical trees bear fruits which are often used for containers or musical instruments and are called gourds. The most common of these is *Crescentia cujete* L., usually called the calabash or gourd tree. It is, however, a member of the Bignoniaceae, the family to which the catalpa tree and trumpet creeper belong. These tropical tree fruits should be called tree gourds to distinguish them from the gourds of the gourd family, Cucurbitaceae (Cutler and Whitaker 1961).

Up to the present time, the most valuable series of prehistoric cucurbits are collections from the Ocampo caves in the state of Tamaulipas in northeastern Mexico (Whitaker, Cutler, and MacNeish 1957). However, the large collection of almost 1400 specimens excavated from five caves in the Tehuacan Valley is at least as important. The collection includes the oldest known specimens of *Cucurbita mixta* Pang., a species most variable in Oaxaca and southern Puebla, and also of *C. moschata* Poir. Also, there is new material of the third annual cultivated species grown in Mexico, *C. pepo* L.

Mexico is the center of greatest diversity of cultivated squashes and pumpkins. All twenty-six wild and cultivated species of *Cucurbita*, except the cultivated South American *C. maxima* Duch., the closely related weedy *C. andreana* Naud. of Argentina, and *C. okeechobeensis* from south-central Florida grow in Mexico and were growing there in prehistoric times (Cutler and Whitaker 1961). Cultivated and wild species are variable, their ranges frequently overlap, and some of the wild species hybridize readily with the cultivated ones. Although we know a great deal about the taxonomy and distribution of the *Cucurbita*, many more collections must be made and many plants grown and studied before the inter-relationships of wild and cultivated species of the genus are reasonably understood.

The best reports of indigenous, cultivated *Cucurbita* of Mexico and Central America were published by Russian botanists after study of plant collections obtained from expeditions led by N. I. Vavilov (Bukasov

1930; Zhiteneva 1930*a*, 1930*b*; Vavilov 1931). K. I. Pangalo (1930) described *C. mixta* from Russian collections made in Mexico.

Collections of *Cucurbita* made by Edgar Anderson, Martin Cardenas, Hugh C. Cutler, Lawrence Kaplan, Carl O. Sauer, Jonathan Sauer, and Thomas W. Whitaker have been grown and studied at the Missouri Botanical Garden, St. Louis, or at the United States Horticultural Field Station, La Jolla, California. A significant collection of cultivated species from Guatemala was grown in Massachusetts by H. E. Moore, and extensive plantings of seeds from many commercial sources have been made by A. M. Rhodes of the University of Illinois. Whitaker and G. N. Davis (1962) published a summary of the available knowledge of cultivated *Cucurbita* and included a concise report of crosses Whitaker made between many cultivated and wild species of the genus. The late Dr. L. H. Bailey (1943, 1948) collected and described most of the wild species in a series of papers illustrated with photographs and excellent pen drawings.

Cutler and Whitaker (1961) described and illustrated the parts of cucurbit plants used to identify archaeological specimens. Peduncles and seeds usually have reliable characteristics for identification of the cultivated species of *Cucurbita*. The rinds, however, with a few exceptions, are of little use. By means of their cell structure, *Cucurbita* rinds can be distinguished from those of the bottle gourd and the tree gourd: but it is presently impossible to identify the species of cultivated *Cucurbita* by rinds alone, except for some forms of *C. mixta* that are marked by prominent corky ridges on the upper portions of the fruit.

The remains of cucurbits found in five dry caves in the Tehuacan Valley—the East Niche of El Riego (Tc 35e), Coxcatlan (Tc 50), San Marcos (Tc 254), Tecorral (Tc 255), and Purron (Tc 272)—were well preserved. It was therefore possible to compare this material directly with other archaeological and recent specimens for size, shape, and structure of the peduncles, seeds, and rinds. Comparisons are more difficult when specimens are carbonized, since partial burning not only destroys some surface features but causes distortion and shrinkage.

Of the four cultivated *Cucurbita* species known from the Tehuacan region today, only *C. ficifolia* Bouché was not found in the Tehuacan caves. It is occasionally seen in the Tehuacan and Ajalpan markets, where it is brought from farms at higher altitudes. As far as we know, it is not grown on the floor of the Tehuacan Valley.

Cucurbita mixta Pang.

The Tehuacan excavations yielded more specimens of mixta than any other species. Practically all the seeds are of a single type, relatively long and narrow, with slightly enlarged margins. In some seeds the corky marginal tissue is silvery gray. The white thickening of the seed body is moderate in all seeds, and there is no furrowing or cracking as there is in the thickened body of typical seeds of the cultivars Japanese Pie and Green Striped Cushaw. Most of the mixta in northern Mexico and the southwestern United States resembles these two cultivars. On the other hand, most of the Tehuacan mixta, archaeological and modern, is similar to the silver-seeded group of Cutler and Whitaker (1956, 1961). Mixta seeds with smooth and thickened brown bodies belong to the Taos group (Cutler and Whitaker 1961) and were found at Tehuacan only in Coxcatlan Cave. There were forty-six seeds of the Taos group in Zone I (Venta Salada phase) and two in Zone VII (Santa Maria phase). One seed from Zone XIV (El Riego phase) may belong to this group.

All of the mixta peduncles found in the Tehuacan caves are moderately corky (Fig. 128). Only a few fragments of rind were found with the corky growths common on the upper portions of mixta fruits grown in northwestern Mexico (Cutler 1960), the southwestern United States, and in the cultivars Japanese Pie and Green Striped Cushaw.

The oldest known mixta seeds come from Coxcatlan Cave. A poorly preserved seed from Zone XIV of the El Riego phase may be mixta. A small seed found in feces in Zone XIII, dating roughly to about 5000 B.C., may also be mixta. A well-preserved peduncle and four seeds from Zone VIII of the Abejas phase of about 3000 B.C. were readily identified as mixta. The latter seeds are similar to those sold in Tehuacan today. The oldest mixta previously known comes from the Ocampo caves in northeastern Mexico and dates from A.D. 150 to 1050 (Whitaker, Cutler, and MacNeish 1957; Cutler and Whitaker 1961).

We expected to find mixta specimens in the older stratigraphic levels of the Tehuacan excavations, since the center of diversity and relative abundance of this species is not far from the Tehuacan area in southern Puebla and Oaxaca. The kinds of mixta recovered from the Tehuacan caves are still found in the vicinity of Tehuacan and to the south and west; they are not found to the north. Mixta fruits were absent from the Tehuacan Valley markets in August 1961 and March 1962. At both times, however, abundant supplies of

Fig. 128. *Cucurbita mixta. Top row:* seeds, Tc 50, Zone VIII (70–8). *Left center:* seed, Taos form, Tc 50, Zone VII (9–4). *Right center:* seed, extreme form of Silver-seeded Gourd, Tehuacan dump. *Bottom:* peduncle, Tc 50, Zone III (33–3). All x 1.5. Photos G. A. Sanderson.

mixta seed were being sold in the markets for roasting, and street-corner vendors were selling small lots of the already roasted seed. Fruits of mixta are sold in the Tehuacan market in late October and November.

A few large seeds of mixta with enlarged silver-gray corky margins were found in debris on a modern dump near the town of Tehuacan (Fig. 128), but no seeds of this type were found in stores and markets and none were found in the caves. Mixta seeds from the Tehuacan caves show less variability than one would anticipate, assuming the location is near the center of origin of the species. The seeds of modern mixta from the Tehuacan area, however, are remarkably uniform, even though the fruits may vary greatly in size, shape, and color.

Cucurbita moschata Poir.

Moschata seeds from the caves are relatively uniform and resemble the kinds grown today in and near the Tehuacan Valley and over much of central and southern Mexico below an elevation of 5000 feet. None of the small, hairy-margined seeds common near Veracruz and in most of southern Mexico and Guatemala were found.

Two seeds found in Coxcatlan Cave at levels attributed to the Coxcatlan phase (about 4900–3500 B.C.) were identified as moschata and are the oldest known seeds of this species. The next oldest specimens, which date from 3000 to 1000 B.C., are from Huaca Prieta, Peru. Specimens from the Ocampo caves of Tamaulipas are dated about 1850 B.C. (Cutler and Whitaker 1961).

A few roasted moschata seeds were sold by street vendors in Tehuacan. Kelly and Palerm (1952) collected cultivars of moschata which are grown only for their seeds in the state of Veracruz, but both seeds and flesh are used in the Tehuacan region. Women in the market report that the common way to prepare moschata is as a sweet, boiled in thick cane syrup. Squash prepared in this way is sold in Tehuacan and other markets and along the roadside. It would be interesting to know whether this modern use of squash is derived from prehistoric times in Mexico. Although prehistoric Mexicans lacked sugar cane, they could have obtained sugar by action of an enzyme on starch, a method well known in Bolivia (Cutler and Cardenas 1947).

Cucurbita pepo L.

Although all but possibly the earliest pepo seed found in the Tehuacan Valley are much more recent than the earliest ones from the Ocampo caves, some

Fig. 129. *Cucurbita pepo. Row 1:* seeds, Tc 35e, Zone A (32–6). *Row 2:* seeds, Tc 35e, Zone C (38–3). *Row 3:* seed, wild form, Tc 50, Zone XIV (148–11). *Row 4:* seeds of fruit from Tehuacan market, March 1962. All x 1.5. Photos G. A. Sanderson.

Fig. 130. Fruits bought in markets near Tehuacan, March 1962. *Left front:* a cultivar of *C. moschata*; others: *C. pepo.*

show close resemblances to the latter group (Fig. 129; see also Fig. 130, center and right; Whitaker, Cutler and MacNeish 1957). What may be the oldest seed of pepo—a single specimen from Coxcatlan Cave, Zone XIV, dating from the El Riego phase of about 5000 B.C.—is similar to the oldest pepo seeds known, those from the Infiernillo culture of the Ocampo caves of about 7000 B.C. It probably came from a wild camp-follower plant growing near the site on disturbed soil. The seed from Coxcatlan Cave is slightly smaller than any of the Ocampo specimens. It approaches in size and shape the larger seeds of the wild *Cucurbita* from later levels of Coxcatlan Cave and those of the wild species that grows in the region today, probably *C. pedatifolia* Bailey.

Other pepo seeds from the caves, like the mixta seeds, are relatively long and narrow. The distribution of long, slender pepo and mixta seeds is not well known, but they have been collected from farms and markets south of Guadalajara, in villages near Oaxaca, through the Tehuacan Valley, and in the vicinity of Veracruz. The pepo and mixta seeds collected from modern Indians or from archaeological sites in northern Mexico and the southwestern United States are relatively broad. The presence of seeds of similar shape in different species occupying approximately the same region suggests the possibility of hybridization. Crosses between mixta and pepo have been reported (see Whitaker and Davis 1962: 106).

Pepo fruits are often stored and can be found at almost any time of year. Stored fruits are sold in the Tehuacan market in March and April. Large numbers of fruits, all with narrow seeds, were seen in Puebla, Cordoba, and Oaxaca in October. Lawrence Kaplan

(personal correspondence) reports that pepo was the only species of *Cucurbita* sold in the Tehuacan market in August 1962. The same cultivar is grown along the Puebla–Mexico highway and is stored on rooftops during the winter. There is little variability in the fruits: those seen in and near Tehuacan were similar to the fruits shown in Fig. 130.

Twenty-six staminate flowers, probably of pepo, were found in Coxcatlan Cave, Zone III (Venta Salada phase). Similar flowers are sold today in the Tehuacan market. They are usually covered with a meal-and-egg batter and are fried or baked.

Wild Species of *Cucurbita*

Fifteen fragments of rinds of a wild *Cucurbita* species, probably *C. pedafolia* Bailey, were identified from Zones D and E to Zone A of the East Niche of El Riego Cave. A peduncle came from a late zone of Coxcatlan Cave. A portion of a fruit and part of the vine were found on a plant growing in 1961 at the mouth of El Riego Cave. Green fruits of practically all species of *Cucurbita* are used throughout Mexico as a laundering detergent and for eating when cooked; the mature fruits are used for the seeds, which are roasted and eaten. Prehistoric Indians probably used the fruits in identical fashion. There is the possibility, however, that some of the specimens in archaeological sites were introduced without the help of man, perhaps even when a site was unoccupied. If so, the most likely source would be weed plants growing on disturbed soils of the site, similar to the plant found in front of El Riego Cave in 1961. The fact that the wild *Cucurbita* specimens from the Tehuacan caves all occur in either late Palo Blanco or Venta Salada levels suggests, however, that they were introduced by man.

There is no evidence that any of the cultivated *Cucurbita* of the Tehuacan caves originated from the wild species found in the vicinity. The distribution of the cultivated species and the evidence of their movement into various areas suggests that there are distinct points of origin for the several species. If any *Cucurbita* was domesticated in the Tehuacan area, it would most likely be mixta, because the center of greatest diversity of this species apparently lies within a few hundred miles of Tehuacan. There is, however, little diversity in the mixta material from the Tehuacan caves and no evidence of change in this species during the thousands of years covered by the Tehuacan deposits.

The wild *Cucurbita* fruits from the caves resemble a mature fruit from a collection made near Tehuacan by J. N. Rose, Joseph H. Painter, and J. S. Rose (their 8994, in the United States National Herbarium) identified as *C. pedatifolia* Bailey. Other species may be present, but it is usually impossible to identify wild cucurbits by fruits alone.

Apodanthera buraeavii Cogn.

Apodanthera, the wild coyote melon, is similar to wild species of *Cucurbita* in many respects, although it is in a distant section of the family Cucurbitaceae. Most of the *Apodanthera* species in Mexico prefer disturbed soils and are often found in the same habitat as wild *Cucurbita* species. The seeds are roasted and eaten by the Indians today; they have also been recovered from several archaeological sites. Identification of *Apodanthera* species from seeds alone is difficult because seeds of a single fruit may vary greatly in size. Also, there are few herbarium specimens with mature fruits, and the nomenclature of the genus is confused. Specimens from Tehuacan probably are *A. buraeavii,* but *A. galeottii* Cogn. and *A. aspera* Cogn. are cited as present in the region.

Apodanthera seeds and a few fragments of fruit were found *only* in the East Niche of El Riego Cave: 11 seeds from Zone A (Fig. 131), 125 from Zone B, and 23 from Zone D. These seeds could have been introduced accidentally by rodents or from fruits which grew near the mouth of the cave. Although a few of the seeds bore the teeth marks of rodents, these marks do not necessarily mean that man did not bring the seeds to the cave. Modern food-gatherers often collect caches of seeds assembled by rodents, and it is likely that the occupants of El Riego Cave did the same.

Lagenaria siceraria (Mol.) Standl.

The oldest known specimens of the white-flowered bottle gourd were found in the Ocampo caves of Tamaulipas in deposits of about 7000 B.C. (Cutler and Whitaker 1961). The bottle gourd is the only cultivated plant which has been found in pre-Columbian deposits in both the Old and the New World. It probably occurred wild in both hemispheres before the development of agriculture. The number of kinds found in the New World is limited, and the center of origin lies in Africa, where more forms and related species grow.

The fragments of bottle-gourd rinds excavated from the Tehuacan caves are similar to specimens excavated from other sites in Mexico and the southwestern United States. There were no seeds to compare with other archaeological specimens.

Crescentia cujete L.

Fragments of the tree gourd were found in most of the Tehuacan sites. The tree gourd comes from a wild

Fig. 131. *Apodanthera* seeds from Tc 35e, Zone A (14–3), x 1.5. Photo G. A. Sanderson.

tree, occasionally planted in the Tehuacan region, as in other parts of the American tropics. The hard shell of the fruit is used to make vessels for eating, drinking, and storage. The small, hard cells of the rind make it easy to distinguish fragments of *C. cujete* from rinds of the bottle gourd or the cultivated and wild species of *Cucurbita,* which have larger and weaker cells (Cutler and Whitaker 1961).

El Riego Cave, East Niche (Tc 35c)

Substantially more intact wild cucurbit specimens were excavated from the East Niche of El Riego Cave than from the other Tehuacan caves. The only *Apodanthera* collections are also from this site. These two observations suggest that more wild *Cucurbita* and *Apodanthera* were growing adjacent to this site than near the other sites excavated, or that El Riego Cave was occupied during the season when these cucurbit fruits were mature, while Coxcatlan and the other caves were not.

Pepo remains are the most numerous of the cultivated squash specimens from El Riego Cave, indicating that it may have been occupied mainly during the spring and summer when stored pepo was almost the only cucurbit available. Two kinds of pepo seeds are present: slender seeds similar to those common in the Tehuacan region today and broader seeds almost identical with seed collected farther north in the Ocampo caves of Tamaulipas and from modern fields and markets in the Ocampo area.

Some of the earliest narrow-seeded, cultivated pepo from Tehuacan dates from the Palo Blanco period (about 200 B.C. to A.D. 500) of El Riego Cave. In Tamaulipas, however, pepo remains appeared in the earliest levels of the Ocampo caves, dating from about 7000 B.C. A few specimens of the other cultivated *Cucurbita,* moschata and mixta, were found in El Riego Cave. However, they do not appear in the two earliest zones, although pepo remains are present.

The cucurbit and tree-gourd material from El Riego and the other caves is summarized in Table 25.

Coxcatlan Cave (Tc 50)

The only pepo specimens from Coxcatlan Cave which we can identify with certainty consist of three peduncles from Zone I and one from Zone II (Venta Salada phase). A single seed from the El Riego phase (Zone XIV) may be an early form of pepo, or it could be a seed from a well-developed fruit of a wild species.

There are scattered moschata specimens from levels assigned to the Venta Salada phase. Two seeds from Zones XI and XII of the Coxcatlan phase are probably moschata.

Mixta is the dominant cultivated species of this site and is abundant through the Abejas phase. A mixta seed was identified in a coprolite from Zone XIII of the Coxcatlan phase. Two seeds from Zone XIV (El Riego phase, roughly 5000 B.C.) probably are mixta; if so, they are the oldest known specimens of this species. The oldest prior recorded collections of mixta, dating from about A.D. 150 to 1050, are from the Ocampo caves.

Far more bottle-gourd specimens in relation to the number of tree-gourd specimens appear in Coxcatlan Cave than in El Riego Cave. This may indicate that the occupants of El Riego Cave relied more heavily on gathering food than those who lived in Coxcatlan. On the other hand, since El Riego Cave is closer to water, its occupants may not have needed gourd vessels in which to store it, whereas the people of Coxcatlan Cave did.

San Marcos Cave (Tc 254)

A single pepo peduncle and five rinds of *Cucurbita* species from Zone B are among the late materials from this site. Five tree-gourd rinds were found in the same zone, which dates from the Palo Blanco phase. A single pepo peduncle from Zone C (Ajalpan phase, about 1000 B.C.) is the earliest cultivated pepo specimen found in the Tehuacan Valley. The total sample is too small for valid comparisons.

Tecorral Cave (Tc 255)

A single slender mixta seed and a fragment of *Cucurbita* species rind in Zone A (Venta Salada phase) are the only cucurbits found in this cave.

Purron Cave (Tc 272)

Zones C, E, and F (Palo Blanco phase) and Zone G (Santa Maria phase) contained the only preserved cucurbit material at this site: three mixta seeds, a pepo seed, and three *Cucurbita* species rind fragments. Five

Table 25. Cucurbit Remains from All Sites by Zone and Phase

	El Riego	Coxcatlan			Abejas			Ajalpan	Santa Maria		Palo Blanco									Venta Salada							
	Tc 50, XIV	Tc 50, XIII	Tc 50, XII	Tc 50, XI	Tc 50, X	Tc 50, IX	Tc 50, VIII	Tc 254, C	Tc 272, G	Tc 50, VII	Tc 272, F	Tc 50, VI	Tc 272, E	Tc 272, C	Tc 50, V	Tc 254, B	Tc 50, IV	Tc 35e, EF	Tc 35e, D	Tc 35e, C	Tc 255, A	Tc 50, III	Tc 35e, B	Tc 50, II	Tc 50, I	Tc 35e, A	Totals
Apodanthera																											
Seeds only																			23				125			11	159
Crescentia cujete																											
Rinds only										1				5		5			2	3		3		1	3	6	29
Wild Cucurbita sp.																											
Rinds																			2			3	1	5	2	2	15
Peduncles																									1		1
C. pepo																											
Flowers																						26					26
Seeds	1†										1							12		8			1			42	65
Peduncles								1?								1?			1	2				1	3	5	14
Cucurbita sp.																											
Rinds only				6			2		1	37		19	1	1	1	5	29	2	22	6	1	105		215	253	62	768
C. moschata																											
Seeds			1?	1		1	1?												1			3	1	26		2	37
Peduncles						1?																1			1	1	4
Lagenaria siceraria																											
Rinds only		1		2	2	2	2			1		3			1		1		2	9		15		11	19	8	79
C. mixta																											
Seeds	2?	1*					4		1	3		2	1	1				2	1		1	8		29	100		156
Peduncles							1			7		3					4		2			19		13	17		66
Totals	3	2	1	9	2	4	10	1	2	49	1	27	2	7	2	11	34	16	56	28	2	183	128	351	399	139	1419

*Found in feces.
†Wild form.

tree-gourd fragments were found at the same levels, dating from about 600 B.C. to the beginning of the Christian era.

Markets are a good index to the principal products of a region. Most Mexican markets and those of parts of Guatemala and the highlands of South America have not changed greatly from pre-Hispanic times, even though many plants and products of European origin have been added to the native wares. In a brief study of the Tehuacan market in 1962, we found eighty-five species of plants used for food (Whitaker and Cutler 1966). Forty-eight are native to the New World, thirty-five to the Old World, and two are common to both hemispheres. In the market we found nearly every kind of cultivated cucurbit represented in the Tehuacan caves. Judging from the few reports we have of cucurbits grown today in northeastern Mexico, we could probably find in the markets and fields of this area the same kinds of cucurbits recovered from the Ocampo caves. The persistence of ancient cultivated types of plants into the present area is well documented in the southwestern United States and in adjacent Mexico.

The pattern of persistence of ancient cultivated types is true to a considerable extent of maize. Some of the ancient kinds of maize may seldom be found, but they may persist if the areas where they are grown have been continuously occupied. Even when the population of an area is replaced by newcomers, the new inhabitants usually take over the cultivated plants of former residents. For example, in the Pueblo Indian area of New Mexico the dominant maize of early periods is still to be found, although now it is grown only as one of several minor kinds.

Summary

Cucurbita mixta is represented by more specimens from the Tehuacan caves than any other species. The earliest known mixta seeds are probably those from Zone XIV of Coxcatlan Cave dating from about 5000 B.C. There is a strong possibility that mixta originated near the Tehuacan region. Several small mixta fruits collected near Tehuacan had rind and seed characters

which suggest that some hybridization with wild species is taking place at the present time. Archaeological and modern specimens of mixta from northern Mexico and the southwestern United States are relatively uniform and can usually be classified as belonging to one of three cultivars: Green Striped Cushaw, Japanese Pie, or Taos. The Tehuacan area is not far from the center of greatest diversity for mixta.

Specimens of *C. pepo* are less abundant in Coxcatlan Cave, but pepo is the dominant species throughout the East Niche of El Riego Cave. This observation suggests that El Riego Cave may have been occupied seasonally, when pepo was abundant. There is little diversity in the pepo of southern Mexico. The species is far more variable to the north and is the only squash which spread to the north and east of the southwestern United States in prehistoric times, reaching as far north as southeastern Canada. In the Ocampo caves of Tamaulipas pepo was found in the earliest levels, perhaps antedating true agriculture, but already showing an increase in seed size over most wild species. This observation suggests that pepo may have been a tolerated weed associate of man prior to the practice of agriculture.

C. moschata is present in small amounts in both caves, almost as early as mixta and probably earlier than pepo. The greatest diversity of moschata is found in the warm regions of coastal and southern Mexico and southward to northern South America. Specimens from Huaca Prieta, Peru, have been dated at about 3000 B.C., but the Tehuacan specimens are older. The Tehuacan Valley is considerably north of the center of diversity for present-day moschata, and it is likely that earlier moschata will be found in sites farther to the south.

The bottle gourd, *Lagenaria siceraria*, was excavated from some of the oldest levels of the Tehuacan caves, along with the cultivated *Cucurbita*. This finding suggests that in the Tehuacan Valley, as in northeastern Mexico, *L. siceraria* was present as early as the oldest cultivated squash or pumpkin and may even have been present as a weed plant in pre-agricultural times.

Specimens of the native wild species of *Cucurbita*, *Apodanthera* (the wild coyote melon), and the bignoniaceous tree-gourd, *Crescentia cujete*, were also found in the caves.

Nearly all of the different kinds of cultivated and wild cucurbits found in the caves are grown in the area today, implying that there has been an essential conservatism in crop husbandry among the various native cultures that developed in Middle America.

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CHAPTER 12

Plant Remains

C. Earle Smith, Jr.

Thousands of plant fragments were recovered from excavations in the Tehuacan region and cover a span of perhaps 9,000 years, beginning before 6500 B.C. These materials were recovered from a total of sixty levels found in six rock shelters: the East Niche of El Riego Cave (Tc 35e), Coxcatlan Cave (Tc 50), San Marcos Cave (Tc 254), Tecorral Cave (Tc 255), Purron Cave (Tc 272), and Abejas Cave (Tc 307). This chapter will treat all but the well-known cultivated plants—corn, squashes, and beans (Chapters 9, 10, and 11)—and plant specimens recovered from coprolites (Chapter 14).

An important facet of the interpretation of archaeological plant remains is the relationship between the plants and the developmental history of the area. Once the lake that covered the valley was drained (see above, Chapter 5), vegetation doubtless rapidly invaded the newly available land—an event accomplished long before man came into the valley. Avenues for invading plants lie along the west side of the Sierra Madre de Oaxaca and up the Rio Balsas Basin from the Pacific Coast of Mexico and are reflected in the current vegetation of the valley. A reconnaissance of the flora of the valley shows the following relationships: species widely distributed in all directions from the area, 50 per cent; species derived primarily from the flora of Northern Mexico and Southwestern United States, 14 per cent; species derived from the vegetation of the Pacific Coast of Mexico, 4.5 per cent; species derived from Southern Mexico, 2.5 per cent; species endemic in the general area, including the southeastward extension of the valley around Tomellin, 29 per cent (Smith 1965*b*).

The last figure, remarkably high for a continental area, probably reflects the extensive period during which there has been a stable climate for the isolation of species particularly adapted to conditions as we now know them in the Tehuacan region. According to the wild plants excavated, there seems to have been no major climatic change over the last 10,000 years, although there is geological evidence that the water table has fallen continuously over this period. The archaeological plant remains from the Tehuacan caves truly constitute an uninterrupted history of the use of plants and their domestication and continued use over thousands of years.

During the earliest periods of occupancy, man was largely a predator of the fauna and flora of the valley. His activities were so closely tied to natural patterns that he made few alterations detrimental to the vegetation. From the time that he first conceived the idea of cultivating certain plants, man began to make important changes in the plant cover of the Tehuacan area. Agriculture in any form implies favoring useful plants over nonuseful plants. The primary aim of the first agriculturists, then, was to encourage certain desirable plants among the local flora. Cultivation can assume many forms, however. In temperate zones, it popularly implies large clear areas devoted to a single crop, or a few kinds of crops. In contrast, the earliest forms of cultivation among the people of the Tehuacan area probably involved only the removal of some unwanted plants from a small patch of ground to make room for a few desirable plants grown from planting either vegetative parts (cuttings or offshoots) or from seeds.

Patterns of Indian agriculture in the Americas are still available for study. The local gardens of the present people of the Tehuacan Valley are good examples

of a kind of agriculture which must have evolved directly from the first attempts at cultivation and have become highly efficient means of food production. Similar gardens in Guatemala have been observed by Edgar Anderson, who suspects that a time study would show that such gardens produce more food per man hour per square foot than the typical, carefully laid out and weeded gardens of this country (1952: 141).

Modern household gardens of Coxcatlan village are examples of Indian cultivation. The areas involved are generally small, not exceeding an acre. Scattered trees, almost all useful to the owners, include American species—*Leucaena esculenta,* mesquite, nanche, white sapote, black sapote, zapote de niño—intermixed with Old World species—orange, lemon, lime, mango, coffee, banana, and others. Planted irregularly in openings are various herbaceous plants, including beans, corn, squashes, and taro, the latter usually in a moist spot. Herbs supplying flavorings, including chili peppers, grow here and there. A few animals and poultry may be kept, but destructive animals like pigs are fenced away from the plants. All household wastes go into the garden, adding to the organic matter in the soil. The garden has no obvious pattern nor is the ground kept clear, but only the most necessary weeding is done.

In pre-Columbian times such gardens must have been planted throughout the Tehuacan Valley. When the Indians cleared space for planting, most useful plants would not have been removed. Mesquite and other species of pod-bearing trees, chupandilla, prickly pear and other edible cacti, and many other species would be left. Among them the farmer would plant such species as he wished to harvest and which would grow successfully in the chosen area. The success of the planted crop would ultimately depend upon the arrival of rain. Thus, the natural vegetation was never completely removed, and after a plot was abandoned, would eventually reclaim it.

At its highest development, dry farming during the rainy season would not expose very large areas of bare soil to erosion. Remains of retaining walls across the beds of barrancas indicate that the Indians recognized the higher fertility and higher moisture content of the alluvial soils of the stream courses. Terracing created in this manner served to spread the water from rainstorms over wider areas and to prevent serious erosion.

The development of irrigation by the Indians probably has had a far greater effect on the vegetation of the valley than the clearing of garden plots. Once an irrigation network was established, with considerable expenditure of energy to dig channels and level plots so the water would spread evenly, gardens would be maintained in the same places until changes in water level or some event such as salting or mineralization forced abandonment. As an irrigation system grew, larger and larger areas would be removed from natural vegetation. The major deterrent to complete removal of the vegetational mantle across the valley would be abrupt changes in level too great to be overcome by hand-grading.

As Jean Brunet has pointed out in Chapter 5, lowering of ground water level followed headward erosion of streams. In a way, irrigation builds into itself a similar factor for lowering the water table. Where formerly all streams in the valley flowed along their courses, on the surface or beneath it, diversion of water from the upper reaches of streams into irrigation systems drastically reduced the volume of water available downstream. The ground water level was inexorably reduced as the irrigation systems drew more and more water out of natural circulation into and through the valley. This, in turn, just as drastically sharpened the hydrostatic gradient in the water table, and upper reaches of the hydrostatic system began to lose water to depleted lower areas, eventually reducing the surface flow into the irrigation channels. If all factors could be precisely measured, it would be possible to forecast the life of any irrigation system in an area of deficit water balance, because the irrigation system will eventually destroy itself.

The slow crawl of the irrigation systems downslope to accommodate the falling water table was accompanied by a crawl of irrigation systems upslope to tap streams ever higher up their courses. Fortunately for the survival of the native vegetation, all fields served by an irrigation system could not be contiguous. Water was fed by gravity and therefore succeeding fields had to be at lower elevations. Frequently areas of natural vegetation which harbored propagules to recolonize abandoned land were left undisturbed.

Soil irrigated by water from mineral springs inevitably becomes mineralized. In years of abundant rainfall, a certain amount of the deposited mineral may be leached from the fields, but generally the process is irreversible. Once many salts have precipitated, particularly calcium salts, they are very difficult to redissolve. The gradual crusting of minerals near the surface of the soil forces the abandonment of fields. Species which can invade such areas are highly tolerant of minerals, and other species are eliminated.

Altogether, agricultural activities in the Tehuacan Valley, particularly at the height of the Indian population, has brought about the successive removal of native vegetation over most of the valley surface. Today, areas

of seemingly primeval vegetation are all second growth, and many areas of fertile soil have probably been cleared and abandoned several times. Because of the mixed nature of Indian farming, however, very few species were eliminated from the vegetation prior to the Spanish conquest.

The coming of the Spanish to Mexico marked a distinct change in methods of farming, though probably not in systems of controlling water, already highly developed by aboriginal engineers. However, the newcomers introduced two immensely destructive forces. The first was the European system of agriculture based on growing a single crop in a cleared field plowed with the aid of draft animals. The second was the introduction of sheep and goats. Herds of these animals swept the vegetation from the surface of the land more completely than any other force. In a short time, hillsides were cleared of their vegetation, which had always tended to absorb and break up the sheets of water from occasional torrential storms. The resulting open soil became susceptible to the destructive forces of sharp, heavy rains.

More damage has probably been done to the native vegetation, to valley land forms, and to the hydrostatic system since the Spanish conquest than was done in all of man's pre-Hispanic occupation of the valley. Byers has pointed out the deficit water balance existing in the area (see above, Chapter 4). Under completely undisturbed conditions, the plants and the animals can reach an equilibrium which conserves as much of the available water as possible. The Indians disturbed this equilibrium during their development of agriculture, but the balance was tilted gently toward the negative side. Practices introduced by the Spanish tilted the balance sharply toward the negative side and accelerated the process of destruction.

While it is true that the pattern of vegetation on the surface of the land has been changing in the Tehuacan Valley, the changes due to disturbance of the ground water level and the hydrostatic system have been changes in degree rather than changes in kind. Plants native to an area persist there because they have within their genetic constitution the plasticity to accommodate to the fluctuating factors in their environment. For example, a heavy growth on the fertile soil along a water course will slowly move to a more favorable environment if the ground water level persistently falls. Pressures of selection occasioned by the loss of ground water will eliminate individual plants which cannot adapt.

Every year, as regular as the weather cycles, the water level in the Tehuacan region rises during the rainy season and falls during the dry season. Any species which can survive the normal dry season can adapt to the gradual changes in ground water supply caused by headward stream erosion, deflection of water for irrigation, or any other cause. Conversely, no plant species can persist in the Tehuacan Valley unless it can adapt to the seasonal variation in available effective water.

Any prolonged departure from the current pattern of a five- or six-month dry season would have permitted a number of species, which are not now present, to invade the Tehuacan region. Because a certain percentage of species of any flora are useful to a gathering people, at least one or two fragments of species suggestive of a climatic difference should have been found among the plant remains. Actually, because all species have a certain amount of tolerance for adverse conditions and because climatic changes are gradual over many years, fragments of species reflecting changes would have been present over a marked time span. No indication was found in the species composition of the plant remains to suggest any climatic change. Furthermore, the species composition of the plant remains from any one site do not suggest any local changes near the site which can be attributed to changes in ground water level over the entire 9000 year period.

In view of the above categorical statements, a discussion of vegetational changes may seem anomalous. In point of fact, it is not. Vegetational changes occurred in the Tehuacan area and are still occurring. The beginnings of agriculture can never be known with exactness. Probably the first areas to be planted and cultivated were plots of alluvial soil newly deposited by a heavy storm or those partially cleared of vegetation by the scouring action of running water. Today and in the past the most likely such areas are in the barrancas along the northeastern side of the valley. Soils here are better watered during the rainy season, increasing the chances of successfully raising a crop. It was along the upper course of these barrancas that the taller montane forest most closely approached the valley floor. The early avocado fruit represented by cotyledons in Coxcatlan Cave may have been gathered from trees growing in the barranca forest. Similarly, the remains of chili pepper recovered from early levels of the cave may have come from plants growing at the margin of the forest. Since the products of both plants are highly desirable, they probably were particularly sought out by occupants of the cave.

The other vegetational change in the Tehuacan region has occurred since the Spanish occupation. Dur-

ing the rainy season, most parts of the area receive enough precipitation to encourage grasses and herbaceous plants which grow, mature their seed, and die within a single season. Open spots probably once became green with low herbaceous plants during the rainy season. Masses of grass remains excavated from caves suggest that moist areas along the stream courses supported stands of setaria and other grasses. In modern times herds of sheep and goats have radically changed this. These animals crop all non-poisonous herbaceous vegetation to the roots before it can mature seeds. The soil in many areas now remains essentially bare.

The presence of setaria and other grasses in the cave deposits is not indicative of a persistently high water table at any time in the past. It merely reflects the lack of herds of animals to deplete the vegetation. Annual plants depend almost exclusively upon the moisture from precipitation to germinate, grow, and mature. Most species have a delayed germination mechanism whereby not all seeds present in the soil will germinate at any one time. If weather conditions cause a crop to fail one year, sufficient seed persists to enable the species to grow and mature another, more favorable year. Although cultivation, carried on in the vicinity of all of the excavation sites, has removed the original plant cover at least once, the complex of species representing the native vegetation has largely managed to repopulate abandoned areas. It is fortunate that this is so, since an understanding of the recovered plant material hinges on a knowledge of the local ecological situation.

We may assume that a major part of the plant material was collected within a radius of twenty miles of a site. Locally available plants were certainly utilized, but desirable plants known to grow a day or more's journey away were sought out when needed. The presence in Coxcatlan Cave on the eastern side of the valley of fragments of "sotolin" (*Beaucarnea gracilis*) and palm (*Brahea dulcis*) which grow on basic soils on the western side of the valley attest to this, as may the presence in El Riego Cave of pochote, which now grows on acidic soils of the northeastern side of the valley. Probably only the most precious commodities would be traded over a considerable distance. Even today, the population of the Tehuacan Valley supplements the tortilla and bean diet with wild plant foods collected in season.

A major problem in the discussion of the plant remains revolves around the use of terms denoting the conditions under which plants grow. The easiest of the words to define is "wild," which refers to those plants that grow untended wherever they find suitable conditions. All of the species recovered from the excavations were wild at some point in their ancestry. If there are plants among the remains which are not now or never could have been native to the area under the climate which is believed to have prevailed over the past 9000 years, then they must have been under cultivation and are, therefore, cultivated plants.

However, the term "cultivation" is relative. Many plant species native to the Tehuacan area are both wild and cultivated today. Mesquite is planted in yards and border rows, where it is cultivated, but it is also wild in the thorn-scrub-cactus forest. Whenever an Indian farmer cleared a small plot but saved the useful species and encouraged them for his own use along with the species which he planted, he was cultivating the plants. If he purposely planted the seed of a native species, the stem joint of a prickly pear, or the offshoot of a maguey plant and gave it cursory care to eliminate competing vegetation, he was cultivating the plants. Many of the native species do not show a marked increase in size or changes in morphology when grown under cultivation, and it is impossible to determine whether fragments representing these species may have come from cultivated plants. Therefore, we cannot say exactly when such plants may first have been cultivated.

"Domesticated" implies far more than "cultivated." Maize, for example, was cultivated before it was domesticated. Once the Indian farmer began actively to select for certain qualities in a plant species, he began the process of domestication. In the case of maize, selection proceeded fairly rapidly, the result being a form of maize which could not propagate itself because it lacked a means to disperse its seeds. It had to be cultivated and was, therefore, completely domesticated. On the basis of fragments of plants, domestication is more difficult to prove. However, if recovered fragments exhibit morphological changes due to active selection, largely increase in size, the plant may be said to be domesticated.

The value of permanent water sources in the valley must have been clear to the early agriculturists. Once the idea of assembling useful species in areas convenient to habitation sites became established, probably initially through the vegetative propagation of such easily cultivable species as prickly pears and maguey, the limitation imposed by the loss of vegetation during the dry season would be apparent. Initial use of spring water probably was no more than the planting of crop plants along the margins of permanent streams. Even this is a form of irrigation, although it consists of bringing the crop to the water instead of

supplying the water to the crop. By elementary ditching to divert small amounts of water from a stream, the early farmers could grow increasing amounts of food during the season when plant food was not plentiful in the thorn-scrub-cactus vegetation of the valley.

The introduction into cultivation and selection for larger fruit size in avocado indicate that the valley farmers were skilled in the use of irrigation. Examples of the vegetation found in the caves suggest that the climate has always been too dry to allow avocados to grow naturally near the sites. By the Santa Maria phase (about 900–200 B.C.), the increase in size of avocado cotyledons provides unmistakable evidence that the tree was not only in cultivation, but that it had been actively selected for increase in fruit size sufficiently long to prevent the large-fruited forms from being completely swamped by the wild-type, small-fruited forms in the system of open pollenation which must have prevailed. Since it takes about seven years for a seedling avocado to come into bearing and trees continue to bear for seventy years or longer, the period of selection prior to its actual documentation by larger cotyledons must have been extensive. Avocados must have been grown under irrigation during the period of development and probably for some time before that.

Irrigation can mean the use of water in many ways. Probably the most primitive form was the planting of crops at streamside so that short ditches could supply water during the dry season. The presence, near Purron Cave, of a dam whose earliest structure dates from 600–800 B.C., indicates that irrigation had progressed far beyond the rudimentary stage at this time, for this large structure would have furnished water for a sizable area. Remains of old irrigation channels are evident from the mineral deposit which accumulated from the water flowing in them. Most of these are difficult to date, but many date from pre-Conquest times.

Ecology of the Excavation Sites

At an altitude of about 1800 meters, the vegetation characteristic of the floor and lower slopes of the Tehuacan Valley gives way to oak and pine forest. Above about 2500 meters, in an area of frequent and sometimes persistent rain, the oak-pine forest changes to montane rain forest. Although many of the plants growing above 1800 meters would be valuable sources of food and raw materials, the archaeological plant remains include no indication that the early inhabitants of the valley regularly frequented the mountain slopes.

Below 1800 meters a forest of spiny shrubs and cacti prevails. This thorn-scrub-cactus forest is of primary interest here, because it was in this zone that aboriginal people developed agriculture. Several facies of this forest occur according to the combination of altitude, precipitation, soils, and drainage. The umbrella-shaped crowns of most of the trees reach a height of six to eight meters, and their branching is frequently tortuous and intertwined. Shrubby vegetation rarely forms a continuous thicket among the trees. Several species of maguey (*Agave* spp.) and prickly pear (*Opuntia* spp.) are to be found among the shrubs, but the most striking feature of this forest is provided by the arborescent cacti, some of which reach a height of ten meters. These include the columnar *Cephalocereus hoppenstedtii*, the irregularly branching jiotilla (*Escontria chiotilla*), the stiffly upright stems of garambullo (*Myrtillocactus geometrizans*), and the spectacular gigantic candelabra of the cardon (*Lemaireocereus weberi*). Most of these bear fruits which, like those of the opuntias, are known as tunas. Among the trees of this forest is one of outstanding economic value, the pochote (*Ceiba parvifolia*). This relative of the giant silk-cotton tree produces large fleshy pods which later open into puffs of white fiber, among which are small black seeds. These are ultilized for food, not only as green, unripe pods, but also as ripe seeds. The roots of the tree are enlarged, fleshy, and rich in starch, and they have served as food for millennia. Other trees in the forest produce edible pods and seeds, and the magueys and prickly pears produce fleshy leaves or stems which were used as food.

Two rather different aspects of this forest can be seen, the one on the northeastern side of the valley where reddish soils are derived from the prevailing acidic rocks composing the Sierra Madre de Oaxaca, the other on the southwestern side of the valley where the substrate consists of travertines, limestones, and marls that allow rapid percolation of moisture and that break down into prevailingly alkaline soils. In some localities water from saline springs has produced an environment suitable only to halophytes, species that will tolerate salt.

In the principal barrancas draining the Sierra Madre there is a more ample supply of water than is found in the surrounding terrain. Although this water cannot always be seen in the arroyo within the barranca, a considerable underflow exists, as is demonstrated by the several methods of tapping it now employed by the barranca-dwellers. If a "barranca forest" formerly existed along the lower reaches of these watercourses, it is difficult of demonstration within the area under consideration because the sides of the barrancas are in-

tensively farmed by people who grow every available fruiting tree, so that no trace remains to show what may have been the aboriginal barranca forest.

El Riego Cave

El Riego Cave, a cavity in the encrusted travertine covering the face of Cerro de la Mesa, is located about four kilometers west of Tehuacan and near the present site of the spring called El Riego. It comprises two niches, an eastern and a western, which bear little stratigraphic relation to each other and are treated as two sites, Tc 35e, and Tc 35w. Because of its situation, water has always been abundant near the cave, although it lies within the zone of least precipitation in the Tehuacan Valley. This water has been used for irrigation purposes since pre-Hispanic times, and although the water table appears to have dropped greatly, it is still a source of water for various purposes.

Abundant supplies of water create oasis conditions at the junction between the alluvial soil of the Tehuacan Valley and Cerro de la Mesa, thus supporting an atypically lush vegetation on the valley floor. Trees now growing in this zone include mesquite (*Prosopis juliflora*), ciruela (*Spondias mombin*), and various pod-bearing trees locally called <u>guaje</u>. The valley floor is irrigated and intensively cultivated. Because of the cultivation it is impossible to determine the original flora of the area, but it seems likely that it included trees and shrubs of economic value that are not now normally found on the west side of the valley.

A few meters above the valley floor the face of Cerro de la Mesa supports the succulents, agaves, and xerophytes of the southwestern side of the valley. A small barranca leads past the mouth of the cave and affords access to the nearly level surface of La Mesa. It seems unlikely that it carries water except at times of extremely heavy rain, because the travertine substrate allows normal rainfall to penetrate readily. There is now insufficient soil in the barranca to make cultivation feasible, and its vegetational cover consists of cacti and spiny shrubs with only rarely a tree of low stature. Prickly pears, magueys, and a species of *Hechtia* are much in evidence. Before the introduction of sheep and goats by the Spaniards, the floor of the barranca was probably covered by a thin grass sward during the rainy season.

The two lowest levels of the East Niche of El Riego Cave, Zones D and E, represent the Palo Blanco phase and the upper three levels, Zones A-C, the Venta Salada phase. The plant remains from each of the five levels show a similar pattern, although a greater variety of plant species and larger amounts of remains were preserved in Zones D and C. Remains of maize—cobs, husks, and loose kernels, numbering altogether in the thousands in some levels—make up the largest portion of the remains. Leaf fragments and chewed quids of maguey are also consistently present in huge amounts. The hundreds of common beans in the upper four zones are notable, as is the greater proportion of *Cucurbita pepo* among the cucurbits from the five zones. Rinds of tree gourds and bottle gourds are also present. The unusually large numbers of white sapote remains in Zone C in relation to remains of other fruits should be noted. This pattern is not reflected in fruit remains from other sites. All the popular fruits of the valley are represented in two or more levels: avocado, chupandilla, cosahuico, ciruela, coyol, and black sapote.

Besides cotton and maguey, which are present in all levels, a number of plants utilized for fiber appear among the remains of Zones D and C: *Brahea dulcis* and *Beaucarnea gracilis*, both of which grow primarily on limestone areas on the west side of the valley; *Tillandsia* spp.; the vine *Cissus*; and *Yucca periculosa* (izote). Among the edible cacti, prickly pear remains are most prominent, but tetecho (*Cephalocereus hoppenstedtii*) and cardon (*Lemaireocereus weberi*) are present in Zones D and C. Zone C also contained one of the few recovered seeds of the poisonous *Thevetia peruviana*. Pochote (*Ceiba parvifolia*) remains, either pods or roots, appeared only in the three earliest levels, and mesquite pods or quids were present in Zones A, C, and D. Fragments of chili pepper occurred in each of the Venta Salada levels, and the grains, amaranth and *Setaria*, were recovered from a few levels. The plant remains from each excavated component are recorded in Table 26.

The appearance of certain plants among the remains tells us something about the seasons during which a site was occupied. To begin at the bottom of the deposit in the East Niche of El Riego Cave, the presence in Zone E of two pochote pods may indicate a spring visit, and the more abundant remains of chupandilla together with two seeds of white sapote, which ripen in the autumn months, show occupancy in the fall. Since numerous fragments of cultivated plants are present, the occupants of Zone E were probably harvesting or planting fields during the times they lived in the cave.

The pattern revealed by the plants from Zone D is similar. The presence of pochote pods, tetecho, and cardon indicate springtime occupancy, and seeds of white sapote, plus one black sapote seed, show residence in the fall.

Fig. 132. Tecorral Canyon; view from San Marcos Cave.

The plant remains in the three Venta Salada levels lack most of the springtime indicators, but at this period, with irrigation well established, the cave may well have been occupied throughout the year. Certainly large crops of corn were being raised, and beans, pumpkins (*Cucurbita pepo*), squash, and cotton were probably planted along with the corn. Fruit trees were probably planted along irrigation ditches or in watered fields.

San Marcos and Tecorral Caves

These two sites are rockshelters in the southwest wall of the headward reaches of Tecorral Canyon. They lie close together, about eight kilometers south-southeast of El Riego Cave, and somewhat more than seven and a half kilometers from the Plaza of Tehuacan, in one of the most arid parts of the valley. Here the scant rain falls on porous sediments and sinks rapidly into the ground. A small watercourse in the canyon shows that it supports an ephemeral stream, probably only during times of very heavy rain, and remains of a very simple irrigation ditch below San Marcos Cave testify either to the optimism of some bygone farmer or to a once greater supply of water than is now available.

In the vicinity of the caves the vegetation has not been recently disturbed except by grazing herds of sheep and goats, but a few hundred yards downstream someone cleared the sparse brush and lechuguilla from a small area. The hillside facing the caves is striped by tall columns of arborescent cacti, among which *Cephalocereus hoppenstedtii* predominates. Darker tufts of the leaves of the izote, prickly pear, and scattered barrel cacti appear among the lighter columns of tetecho. An occasional bulbous-trunked sotolin (*Beaucarnea gracilis*) projects above the spiny shrubs, but this tree is by no means common in this vicinity. The vegetation in the upper parts of the canyon, dominated by spiny shrubs, lacks some of the members of this association prominent on the northeastern side of the valley. Herbaceous plants are few, since they succumb to the grazing animals. The vegetation appears to have reached maturity, but it is largely second growth, the canyon floor and the less-steep slopes having once been cultivated.

No form of cultivation is undertaken in Tecorral Canyon today. The small clearing mentioned above looks as though it were an attempt to develop a small patch of corn with dry-farming techniques. By means of deep, contour furrows and seed planted in holes in the furrow, the farmers of the dry, western side of the Tehuacan Valley manage to harvest a crop during the rainy season. Both maize and beans are seeded in a mixed planting. The cultivars grown by this technique appear to stand without growth during periods of drought with little harmful effect. With the advent of rain, rapid growth is resumed. Vestiges of old check dams and terrace walls demonstrate that the canyon floor was once cultivated by dry-farming techniques. There is at present no source of irrigation water upgrade in the area. However, the presence of subsurface water is attested to by the remains of an old tunnel system and fresh spoil-piles from a recently improved irrigation tunnel leading into the mouth of the canyon. That part of Tecorral Canyon described by Flannery (Chapter 8) lies in this lower part.

The plant remains from Tecorral Cave (Tc 255) are few and appear late in the sequence of cultural development. Only Zone A (Venta Salada phase), contained preserved plant fragments, including remains of cotton, squash, and maize.

San Marcos Cave (Tc 254) contained a deposit extending from Zone F (Coxcatlan phase) to Zone B (Palo Blanco phase). Plant remains were not very abundant in the earlier levels, but extensive remains of maize and maguey show an unbroken sequence over the entire period covered by the deposit. The maize further shows evolution from wild to domesticated forms (Chapter 9).

Much of the plant material is representative of the natural vegetation adjacent to the cave. Several species of "guaje" (a generic term for pods of leguminous trees of the genera *Acacia*, *Leucaena*, *Mimosa*, and *Pithecolobium*) were present from Zone E (Coxcatlan phase) on. A number of *Jatropha neopauciflora* seeds were preserved in Zone B. Among the local fiber plants, maguey, *Brahea dulcis*, *Hechtia* sp., *Tillandsia* spp. (including *T. dasilyriifolia*), *Beaucarnea gracilis*, *Yucca periculosa*, and *Cissus* sp. were represented in one or two of the Palo Blanco levels, and seeds of *Beaucarnea* and yucca were found in Zone C (Ajalpan phase). From Zone E on, pochote pods are present, attesting to springtime occupancy. (This plant was not observed in the vicinity of Tecorral Canyon in the survey.) Remains of mesquite—quids or seeds—are fairly numerous in the last three levels, but stem fragments of *Opuntia* appear only twice, in Zone D (Abejas phase) and in Zone B. Tetecho, also appearing in two levels, is the only other cactus represented.

Besides maize, plants that might be attributable to cultivation are not numerous and appear only in later levels. Scraps of cotton fiber were recovered from Zones D (Abejas phase), C (Ajalpan phase), and B (Palo Blanco phase). The amaranth in Zones B and C was probably derived from cultivated plants, and the setaria seed from Zone C^1 may have been cultivated. No beans were recovered, and cucurbit fragments are few. Remains of fruit are scant, consisting only of one chupandilla seed, one cosahuico seed, three white sapote seeds, and six seeds of *Bumelia laetevirens*—all from Zone B. The only samples of ground cherry, or "tomate" (*Physalis* sp.), recovered from any of the sites were 28 fragments in Zone C^1 and 25 in Zone B. These may or may not come from cultivated plants.

The plant remains from San Marcos Cave do not give as much evidence as we could wish about the seasonal occupation of the sites, for the fall-ripening fruits are absent from all but Zone B. However, the presence of pochote pods from Zone E (Coxcatlan phase) on indicates that the cave was visited during the spring, probably when the fields were planted. Caches of mesquite seed could have been left from the spring visits or may indicate summer visits. If crops of maize were grown without irrigation, they would have been harvested by groups living in the cave during the autumn.

Abejas and Purron Caves

These two caves in the Arroyo Lencho Diego are located on the eastern side of the Rio Salado, where the reddish soil, primarily derived from acidic rocks, supports a fairly uniform thorn-scrub-cactus vegetation. Coxcatlan Cave also lies within this area. Abejas Cave (Tc 307) lies in the southwestern side of the canyon, where a small branch to the northwestward leaves the main canyon. Purron Cave (Tc 272) is only a short distance away, below a steep cliff on the eastern side of this small branch and very close to the facing canyon wall. It must have been well sheltered from inclement weather, and it is well heated by the afternoon sun. The canyon is now covered with spiny shrubs and small trees, punctuated by scattered columnar cacti, *Cephalocereus hoppenstedtii*. A large dam of earth and masonry was built across the arroyo at Mequitongo in pre-Hispanic time, and this has materially altered the floor of the canyon by reason of sedimentation above it. The unnaturally smooth surface of the ground is covered with a growth of cryptogamous plants. In the better-watered bottom of the ravine, the cover of trees of the families Leguminosae, Burseraceae, Anacardi-

Fig. 133. Purron Cave as seen from the opposite side of the canyon.

aceae, and others is interspersed with arboreal cacti and spiny shrubs of many families. As the ground begins to slope upward along the margins of the canyon, the trees are more widely scattered. Where increasing slope allows more drainage, the arborescent cacti become dominant, and the tree cover is sparse. Maguey plants are usually found up the slopes on the better-drained areas. Among the native plants are many that were gathered by the occupants of the caves—including pochote, guaje, prickly pear and other cacti, chupandilla, chololo, maguey, and the various grasses.

The excavation of Abejas Cave produced very few plant remains. A small quantity of maize appeared in one level of the Palo Blanco phase. In Zone B three maguey quids and ten fragments of maguey leaves were found.

Purron Cave, on the other hand, though preservation was spotty, yielded a variety of fragments, some few of which extend back to the El Riego phase of 6500–5000 B.C. In Zone R two seeds of the fruit chupandilla were preserved, along with one cosahuico seed and two fragments of maguey leaves.

Preservation was poor through the next several levels (Q and Q^1 of the Coxcatlan phase and N^1-L of the Abejas phase). The only vegetal remains were fragments of maguey and bits of wood and bark.

The zones representing the Purron phase, K and K^1, contained a few maize cobs, a few chupandilla seeds, one coyol seed, two maguey fragments, two pochote pod fragments, and the usual wood and bark. These remains may represent spring and fall visits, or perhaps occupation throughout the rainy season.

Zone J of the Ajalpan phase contained twelve maize cobs, one cosahuico and one coyol seed, a nopal (*Opuntia* stem) fragment, and two maguey fragments. The meager evidence hints at a summer or fall occupation.

Zones I-G represent the Santa Maria phase of Purron Cave.The numbers of specimens and the species represented begin to increase in these levels. Remains of maize, for instance, number 10 in Zone I, 12 in Zone H, and 30 in Zone G. Maguey leaf fragments increase from 6 in Zone I to a startling 863 in Zone H, to 146 in Zone G, and maguey quids increase from one to 42 over the three levels. Fruit remains follow the same trend, and some species appear for the first time, as the accompanying tabulation shows. The large earthen dam mentioned earlier was apparently built some time between the occupations of Zones I and H. The effects of its presence may be reflected by increases in the plant remains in Zone H and later levels. Note that remains of black and white sapotes appear in Zone H, after the dam would have provided water for irrigation. The absence of black sapote remains in all but one of these later levels is surprising and is probably owing to poor preservation, since remains from Coxcatlan and El Riego caves demonstrate this fruit's popularity.

	Zone I	*Zone H*	*Zone G*
Avocado	0	1	5
Chupandilla	3	4	26
Cosahuico	3	1	194
Coyol	4	0	7
White sapote	0	1	4
Black sapote	0	1	0

Among the fiber plants besides maguey, cotton was identified in Zone H and all subsequent levels, and *Beaucarnea gracilis* and yucca were present in Zone H alone. Annual crop plants in addition to maize and cotton include squash (*Cucurbita mixta* and unidentified *Cucurbita* sp. rinds).

Since the plant remains in all three levels contained both spring- and fall-ripening species, the pattern of occupation was either throughout the growing season or during spring and fall visits to plant and harvest crops.

The Palo Blanco phase of Purron Cave is represented by Zones F through A. The trend of increasing quantities in some cases is maintained throughout the six zones. Remains of maize, for instance, number 40 in Zone F and 198 in Zone A. The number of maguey leaves rises from a low of 193 in Zone F to a high of 1,396 in Zone B and drops in Zone A to 229. Zones E and C also contained over a thousand leaf fragments each.

Most of the fruit remains follow a somewhat different trend. After increasing to large amounts—sometimes

Fig. 134. Coxcatlan Cave during the dry season. The deciduous nature of the vegetation is clearly seen. The man standing on the talus demonstrates the scale of the shelter which extends across the face.

	Zone F	Zone E	Zone D	Zone C	Zone B	Zone A
Avocado	0	0	6	0	0	0
Chupandilla	48	923	249	61	54	124
Cosahuico	92	30	33	0	1	4
Coyol	37	68	68	18	0	1
White sapote	3	4	3	0	0	0
Black sapote	0	0	0	0	0	0
Guava	0	4	0	0	0	0

numbering in the hundreds (see accompanying tabulation)—in Zones F to D, they then appear in diminishing quantities or not at all from Zones C to A. The fact that the large dam in the area apparently no longer functioned after Zone D may account for the decreases in the later levels. Of particular interest is the finding of four guava fragments in Zone E—the only finds of this definitely cultivated fruit in the plant remains from all the sites.

Among the fragments of *Opuntia* recovered from Purron Cave are the remains of fruit and stems in Zone E and of stems in Zone D. Other naturally occurring species represented in these levels are *Jatropha neopauciflora,* pochote (pods and roots), yucca, tetecho, garambullo, and *Mammillaria* sp. Six mesquite quids from Zone B were the only specimens of this plant found in the upper levels of Purron Cave. The only other mesquite remains were eight quids from Zone J.

The remains from the Palo Blanco zones show the same seasonal pattern as the previous zones. Pochote pod fragments indicate spring occupancy and the fall-ripening fruits are evidence of occupation in the fall.

The plant remains from Purron Cave show an unusually continuous pattern from the Purron phase through the Palo Blanco phase. Remains of plants attributable to cultivation in every level are proportionally larger than remains of wild plants—assuming that most of the large amounts of maguey remains came from a permanent planting. This planting could have covered an extensive area and would have been cut

Fig. 135. View from Coxcatlan Cave showing the forest of thorny shrubs and cactus in the dry season. A forest of oak and pine originally extended to the lower edge of the montane fields. See Fig. 93 for view of the same country in the wet season.

annually, perhaps largely for the extraction of fiber. Crops of cotton, maize, and squash were planted and harvested yearly. The area also seems to have contained orchards where such trees as coyol, avocado, ciruela, chupandilla, cosahuico, and white sapote were grown under irrigation. The largest increases in remains of these fruits occur during the late Santa Maria and early Palo Blanco occupations—precisely when the archaeological evidence shows that a dam provided standing water in the area. This dam ceased to function some time between the occupations of Zones D and C (Palo Blanco phase). It is interesting to note that whereas the amounts of recovered maize cobs increase in the later Palo Blanco zones and the amounts of maguey remain large, the fruits—most of which had to be irrigated to survive—consistently diminish after Zone D, the last occupation when the dam was functioning, and further, they are almost nonexistent before Zones H and I, when the dam was built. This is strong evidence for concluding that avocado, ciruela, cosahuico, coyol, and chupandilla were grown under cultivation and is in agreement with conclusions based on the increased seed size noted for some of these plants. One should note as well the abundance of most of these fruits in the Santa Maria and Palo Blanco levels of Coxcatlan Cave (see Table 26).

Coxcatlan Cave

By far the largest amount of plant remains comes from twenty-four of the twenty-eight levels of Coxcatlan Cave. This large rock shelter in a northward-facing cliff looks out over the gently rolling slopes of the Sierra Madre de Oaxaca. Directly in front of the cave a watercourse carries water only after heavy rains and shortly joins similar streams. This is an area of shallow valleys and gentle hills adaptable to cultivation. That the area was once extensively farmed is demonstrated by house mounds and foundations scattered through the rich stand of thorn-scrub-cactus forest that now covers the land. The native wild plants found in Coxcatlan Cave are today available in the nearby vegetation and certainly must have been available to the aboriginal inhabitants of the cave.

In the valley bottoms and on the gentle slopes a thin

Fig. 136. Garambullo *(Myrtillocactus geometrizans)* in flower.

cover of trees about eight meters tall is intermingled with arborescent cacti. Common trees growing across the hills are *Acacia subangulata* Rose, *Cassia pringlei* Rose, *Acacia villosa* (Sw.) Willd., *Acacia cymbispina* Sprague and Riley, and *Acacia sericea* M. and S.—all lacy foliaged members of the *Leguminosae*. Green and red marble-like fruits readily identify cholulo, *Zizyphus pedunculatus*. Scattered trees of pochote, *Ceiba parvifolia*, project above the canopy, displaying puffs of silver at the end of the dry season.

Intermixed with the trees, or sometimes in nearly pure stands, arboreal cacti raise their columns of yellow-green, gray-green, or blue-green above the canopy. *Escontria chiotilla* is laxly, irregularly branched and bears both yellow flowers and fruit near the start of the rainy season. The straight, upright stems of *Myrtillocactus geometrizans* frequently have rows of tiny glaucous fruit along the crests of the ridges. The fuzzy columns of *Cephalocereus* spp. and the huge candelabras of *Lemaireocereus weberi* dominate some of the better drained slopes.

Growing among the trees are numerous shrubs, usually with intertwined spiny twigs, such as *Castela tortuosa, Bursera arida, Jatropha dioica,* and *J. neopauciflora*. Large clumps of *Opuntia hyptiacantha* and *O. pilifera* bear numerous edible, red prickly pears or tunas. On the well-drained slopes above the cave and on hills nearby, *Agave macroacantha* forms colonies of rosettes, but the stalked lechuguilla, *Agave karwinskii,* and the sessile *Agave rubescens* occur as solitary plants.

Scattered through the trees and shrubs are a surprising variety of herbaceous plants. During the rainy season numerous composites like *Sanvitalia fruticosa* Hemsl., *Tridax procumbens* L., and *Pectis canescens* HBK. intermingle with fragile plants of *Oxalis neaei* DC., *O. berlandieri* Torr., *Commelina erecta* L., and *C. dianthefolia* Del. After a rain, the resurrection plant, *Salaginella lepidophylla* Spring., lies flat to expose its bright green top, but it remains rolled into a tight brownish ball when the weather is dry. *Tillandsia recurvata* L. is frequently seen as an epiphyte on the trees and arborescent cacti. Grasses probably once formed an important part of the herbaceous vegetation, but sheep and goats have altered the composition of the herbaceous flora.

The plant remains from zones of Coxcatlan Cave dating to the Ajuereado phase are few but interesting. The earliest level in which any perishable vegetal fragments survived was Zone XXVI, probably dating to about 7000 B. C. In this level was one seed of mesquite, a fragment of palm leaf, and two clumps of grass. Mesquite remains were found throughout the deposits of this cave and others. *Brahea dulcis,* the palm species present, reappears only in Zone XVI, but it too is represented in other deposits and must have served as a source of fiber from earliest times.

Zone XXV yielded no perishable remains at all, but Zone XXIV contained identifiable fragments of food plants which have been used by the inhabitants of the valley for several millennia. Among these were a few seeds of the wild grass setaria, one amaranth seed, prickly pear seeds, one avocado cotyledon, and a seed of chupandilla. With the exception of setaria, these species are still widely used in cultivated or wild forms today.

Preservation was poor in Zone XXIII, the latest Ajuereado zone, which contained only a few seeds, identified as setaria, mesquite, and prickly pear. There

Fig. 137. Fluffs of pochote *(Ceiba parvifolia)* burst from the pods late in the dry season.

was also a questionable stem fragment of the latter cactus.

Zones XXII through XIV represent the El Riego phase, which dates from after 6500 to about 5000 B.C. Preservation in the earlier of these zones was poor. The paucity of wood and bark fragments below Zone XVI suggests that the deposit was subjected to moisture, resulting in deterioration of less durable plant fragments. Most of the remains in levels XXII–XVIII (nothing perishable came from Zone XVII) were in the form of seeds. These represent avocado, setaria and other grasses, amaranth, *Acacia, Jatropha,* and *Condalia* spp., and two cacti, *Opuntia* sp. and *Lemaireocereus hollianus.* The earliest seeds of the fruit cosahuico also appeared in Zone XVIII. All the seeds would persist under adverse conditions because seed coats are more impervious to moisture than other plant parts. However, fragments of prickly pear fruits and the earliest preserved fragments of maguey leaves also came from these levels. The chili pepper first appears as a questionable fragment in Zone XXI and again, this time definitely, in Zone XIX.

The three later zones of the El Riego phase, XIV–XVI, contained a variety of plant species, usually preserved in increasing numbers. Caches of setaria and grass seed in the three zones total about 180 ounces and show that these grains may have been stored for use when other plant foods were scarce. Traces of amaranth were also identified in these zones. Other plants present were guaje (*Leucaena esculenta*), mesquite, pochote (*Ceiba parvifolia*) pods (the earliest record for this species), chili pepper, various cacti (*Opuntia, Cephalocereus hoppenstedtii, Lemaireocereus hollianus*), maguey (both quids and leaves), the tree gourd (*Crescentia*), *Cucurbita pepo* (probably a wild form), two cultivated squash seeds (probably *C. mixta*), and surprisingly, cotton (two unmistakable boll fragments from Zone XVI). The next earliest cotton fragments were found in an Abejas phase level of San Marcos Cave. No cotton remains representing the intervening Coxcatlan phase were recovered.

Fruits native to the valley or the barranca forests were represented in the four El Riego zones with the

	Zone XVIII	*Zone XVI*	*Zone XV*	*Zone XIV*
Avocado	8	7	11	5
Chupandilla	0	37	3	1
Ciruela	?	200	1	0
Cosahuico	2	5	0	2

best preservation, as shown in the accompanying tabulation. Two of these fruits, avocado and chupandilla, extend back to the very earliest zones with perishable remains. All of them appear in increasing amounts throughout the remainder of the Coxcatlan Cave deposit.

Little can be deduced from the plant remains concerning the seasons of occupation of the El Riego phase other than that the cave seems to have been inhabited, or at least visited, during the summer and fall when the *Jatropha neopauciflora* seeds (Zones XXII–XX) and chupandilla (Zones XVII–XIV) and cosahuico seeds (Zones XVIII–XVI and XIV) were available. Increasing amounts of setaria seed may be interpreted as an indication that setaria may have been sown and harvested near the site, which would require occupation at the beginning and end of the rainy season. In view of the developing cultivation of crops in the succeeding Coxcatlan phase, it is not unlikely that in later El Riego times experiments in the planting of desirable native plants such as avocado, maguey, and prickly pear required attendance of the people for most of the rainy season from May through October.

The Coxcatlan phase, extending from about 5000 to 3500 B.C., is represented by Zones XIII through XI. Although as a group the plant materials from this horizon reflect marked dependence on wild plants for food, it is in these zones that the modern Mexican diet based on maize, squash, beans, and chili pepper becomes discernible. Maize cobs appear for the first time in Zone XIII and again in the two more recent zones. In all three levels, the cobs are small in size and few in proportion to other plant fragments. The squash remains are even fewer and consist of one or two seeds of *Cucurbita moschata* and a seed of *C. mixta* recovered from a coprolite. *Lagenaria,* or bottle gourd, rinds also appear in two of the three levels. The com-

Table 26. Remains of Food and Fiber Plants from All Sites by Zone and Phase

Ajuereado and El Riego

	AJUEREADO			EL RIEGO								
	Tc 50, XXVI	Tc 50, XXIV	Tc 50, XXIII	Tc 50, XXII	Tc 50, XXI	Tc 50, XX	Tc 50, XIX	Tc 50, XVIII	Tc 272, R	Tc 50, XVI	Tc 50, XV	Tc 50, XIV
FOOD PLANTS												
Dioon edule												
Setaria cf. macrostachya		*	0.5oz.	0.01oz.	0.06oz.	0.1oz.	2oz.	0.07oz.		12.2oz.	13oz.	19oz.
Unidentified grass seed		*		0.01oz.		0.1oz.	1oz.	0.02oz.		33oz.	10.8oz.	45oz.
Grass quids										1	3	4
Zea mays (maize)												
Acrocomia mexicana (coyol)												
Amaranthus spp.		*					?	*		*	*	*
Persea americana (avocado)		1						8		7	11	5
Acacia spp.: pods												
seeds					1oz.							1oz.
Acacia sericea: pods												
Arachis hypogaea (peanut)												
Canavalia sp. (jack bean)												
Leucaena esculenta										4		
Phaseolus acutifolius (tepary bean)												
P. coccineus (runner bean)												
P. lunatus (sieva bean)												
P. vulgaris (common bean)												
Prosopis juliflora: pods												2
(mesquite) seeds	1		*				0.05oz.	0.02oz.		10oz.	13oz.	29oz.
quids												
Casimiroa edulis (white bean)												
Malphigia sp.												
Jatropha neopauciflora				1	5	2						110
Jathropha sp.												
Cyrtocarpa procera (chupandilla)		1							2	37	3	1
Spondias mombin (ciruela)										200	1	
Condalia mexicana						1						2
Ceiba parvifolia: roots												
(pochote) pods										1		3
Cephalocereus hoppenstedtii (tetecho)										1		1
Escontria chiotilla (jiotilla)												
Lemaireocereus hollianus: seed				*	*					5oz.	0.3oz.	5oz.
stem										1		
L. stellatus: fruit												
L. weberi (cardon): fruit											2	
Myrtillocactus geometrizans (garambulo)											1	
Opuntia spp.: leaves		*	*	*							1	10
(prickly seeds		*	*	*	*			0.03oz.		0.03oz.	0.3oz.	5oz.
pear) fruit		1		3			1	1		1		
Psidium guajava (guava)												
Bumelia laetevirens												
Sideroxylon cf. tempisque (cosahuico)								2	1	5		2
Diospyros digyna (black sapote)												
Capsicum annuum (chili pepper)							1			1	3	31
Physalis sp. (tomate)												
Crescentia cujete (tree gourd)												
Unidentified Cucurbita spp. (squashes & pumpkins)												
C. mixta												2?
C. moschata												
C. pepo												1w
Lagenaria siceraria (bottle gourd)												
Apodanthera sp.												
FOOD AND FIBER												
Agave spp.: quids								1		23	21	19
leaves						2		3	2	7	2	31
seeds												
fiber												
Yucca periculosa: leaves												
seeds										2oz.		
FIBER PLANTS												
Brahea dulcis (palm)	1									10		
Hechtia sp.												
Tillandsia spp.: leaves												
spikes												
Tillandsia dasyliriifolia												
Beaucarnea gracilis (sotolin)												
Agave kerchovei: stems												
Cissus sp.												
Gossypium hirsutum (cotton)										2		
OTHER USES												
Selaginella sp.												
Grasses (unidentified)	2					3					*	
Agave sp.: spine												
Dioscorea sp.: inflorescence												
Quercus sp.: acorn												
Caesalpinia sp.												
Leucaena pueblana: pods												
Mimosa sp.: pods												
Jatropha sp.: seed												
Zizyphus pendunculatus (cholulo)												
Mammillaria sp. (bisnaga)												
Plumeria rubra (frangipani)												
Thevetia peruviana												
Bark						2		3		2	5	1
Wood						3					17	28

Coxcatlan and Abejas

	COXCATLAN							ABEJAS						
	Tc 50, XIII	Tc 272, Q	Tc 50, XII	Tc 254, F	Tc 254, E	Tc 50, XI	Tc 272, Q'	Tc 50, X	Tc 254, D	Tc 272, NV	Tc 50, IX	Tc 50, VIII	Tc 272, M	Tc 272, L
FOOD PLANTS														
Dioon edule			1			7		1						
Setaria cf. macrostachya	2.8oz.		16.5oz.			26.6oz.		*			4.6oz.	9.5oz.		
Unidentified grass seed	1oz.		90oz.			8oz.			1oz.		2oz.			
Grass quids	7		5		1	52		1	7		14	14		
Zea mays (maize)	18		5	1	35	33		2	114		33	24		
Acrocomia mexicana (coyol)			4			7					1			
Amaranthus spp.			1oz.					1oz.			1oz.	1oz.		
Persea americana (avocado)			1			32					2	4		
Acacia spp.: pods			4			1						2		
seeds			0.01oz.			2oz.					0.01oz.	0.01oz.		
Acacia sericea: pods						1						2		
Arachis hypogaea (peanut)														
Canavalia sp. (jack bean)												1		
Leucaena esculenta	1								4			1		
Phaseolus acutifolius (tepary bean)												118s		
P. coccineus (runner bean)														
P. lunatus (sieva bean)														
P. vulgaris (common bean)						1						1		
Prosopis juliflora: pods														
(mesquite) seeds	12oz.		23oz.			25oz.					64oz.	6oz.		
quids				1										
Casimiroa edulis (white bean)						4					1	9		
Malphigia sp.	1		2											
Jatropha neopauciflora	13		4			63					5	10		
Jathropha sp.														
Cyrtocarpa procera (chupandilla)	22		78			1159		1			1	28		
Spondias mombin (ciruela)	5					4		2				3		
Condalia mexicana	30		1000			78					176	83		
Ceiba parvifolia: roots	1					24					39	1		
(pochote) pods	46		23		1	177		10	5		113	174		
Cephalocereus hoppenstedtii (tetecho)	1		1oz.s			3								
Escontria chiotilla (jiotilla)						1								
Lemaireocereus hollianus: seed	1oz.					102oz.								
stem												2oz.		
L. stellatus: fruit														
L. weberi (cardon): fruit			2											
Myrtillocactus geometrizans (garambulo)											2	3		
Opuntia spp.: leaves	6		8			57		29	1		15	4		
(prickly seeds	13oz.		3oz.			9oz.		10oz.			1oz.	*		
pear) fruit			1			2		1			50	18		
Psidium guajava (guava)														
Bumelia laetevirens														
Sideroxylon cf. tempisque (cosahuico)	5		11			271		3			1	2		
Diospyros digyna (black sapote)						2		5			50	6		
Capsicum annuum (chili pepper)	1		1			3					3	4		
Physalis sp. (tomate)														
Crescentia cujete (tree gourd)														
Unidentified Cucurbita spp. (squashes & pumpkins)						6						2		
C. mixta	1f											5		
C. moschata			1?			1					2	1		
C. pepo														
Lagenaria siceraria (bottle gourd)	1					2		2			2	2		
Apodanthera sp.														
FOOD AND FIBER														
Agave spp.: quids	63		106	5	160	342		65	161		62	238	1	
leaves	74	1	178	3	8	344	1	30	93	1	489	805		1
seeds											1oz.			
fiber									44oz.					
Yucca periculosa: leaves						1								
seeds	2oz.		1oz.											
FIBER PLANTS														
Brahea dulcis (palm)														
Hechtia sp.									1					
Tillandsia spp.: leaves														
spikes														
Tillandsia dasyliriifolia	1					7					15	30		
Beaucarnea gracilis (sotolin)						4								
Agave kerchovei: stems														
Cissus sp.						2						8		
Gossypium hirsutum (cotton)									2					
OTHER USES														
Selaginella sp.														
Grasses (unidentified)			1			4						8		
Agave sp.: spine				1										
Dioscorea sp.: inflorescence														
Quercus sp.: acorn						2								
Caesalpinia sp.					1									
Leucaena pueblana: pods														
Mimosa sp.: pods					2									
Jatropha sp.: seed														
Zizyphus pendunculatus (cholulo)														
Mammillaria sp. (bisnaga)														
Plumeria rubra (frangipani)						1								
Thevetia peruviana														
Bark	30		20		2	78		22		5	54	66	1	3
Wood	73		58	2	2	191		62	26	8	262	371	7	16

Purron, Ajalpan and Santa Maria

	PURRON		AJALPAN		SANTA MARIA			
	Tc 272, K	Tc 272, K'	Tc 272, J	Tc 254, C	Tc 272, I	Tc 272, H	Tc 272, G	Tc 50, VII
FOOD PLANTS								
Dioon edule								13
Setaria cf. macrostachya								6.5oz.
Unidentified grass seed								
Grass quids			6	18	2		4	68
Zea mays (maize)	2	4	20	229	21	25	37	719
Acrocomia mexicana (coyol)	1		1				7	6
Amaranthus spp.								1oz.
Persea americana (avocado)						1	5	35
Acacia spp.: pods								3
seeds								
Acacia sericea: pods								
Arachis hypogaea (peanut)								
Canavalia sp. (jack bean)								
Leucaena esculenta				27				8
Phaseolus acutifolius (tepary bean)								
P. coccineus (runner bean)								1s
P. lunatus (sieva bean)								
P. vulgaris (common bean)								
Prosopis juliflora: pods								3
(mesquite) seeds				2				85oz.
quids				3				91
Casimiroa edulis (white bean)						1	4	7
Malphigia sp.								
Jatropha neopauciflora							2	82
Jathropha sp.								1
Cyrtocarpa procera (chupandilla)	1	2			3	4	26	979
Spondias mombin (ciruela)							2	57
Condalia mexicana								10
Ceiba parvifolia: roots								315
(pochote) pods	2			2	1			165
Cephalocereus hoppenstedtii (tetecho)				2				1
Escontria chiotilla (jiotilla)								
Lemaireocereus hollianus: seed								
stem								
L. stellatus: fruit								
L. weberi (cardon): fruit								10
Myrtillocactus geometrizans (garambulo)								
Opuntia spp.: leaves			1					26
(prickly seeds								*
pear) fruit								54
Psidium guajava (guava)								
Bumelia laetevirens								3
Sideroxylon cf. tempisque (cosahuico)			1		3	1	194	166
Diospyros digyna (black sapote)						1		13
Capsicum annuum (chili pepper)								5
Physalis sp. (tomate)								
Crescentia cujete (tree gourd)								1
Unidentified Cucurbita spp. (squashes & pumpkins)							1	37
C. mixta							1	10
C. moschata								
C. pepo				1				
Lagenaria siceraria (bottle gourd)								1
Apodanthera sp.								
FOOD AND FIBER								
Agave spp.: quids				28	1	4	42	486
leaves	2		2	50	6	863	146	7
seeds								
fiber				10oz.				
Yucca periculosa: leaves				1		1		
seeds				2oz.				
FIBER PLANTS								
Brahea dulcis (palm)								
Hechtia sp.								1
Tillandsia spp.: leaves								
spikes								
Tillandsia dasyliriifolia								24
Beaucarnea gracilis (sotolin)						1		
Agave kerchovei: stems								
Cissus sp.								43
Gossypium hirsutum (cotton)				1		1	*	2
OTHER USES								
Selaginella sp.								*
Grasses (unidentified)				112oz.			*	12
Agave sp.: spine								
Dioscorea sp.: inflorescence								1
Quercus sp.: acorn								
Caesalpinia sp.								
Leucaena pueblana: pods								
Mimosa sp.: pods								
Jatropha sp.: seed								1
Zizyphus pendunculatus (cholulo)								2
Mammillaria sp. (bisnaga)								
Plumeria rubra (frangipani)								
Thevetia peruviana								
Bark	16	1	15	3	9	13	40	134
Wood	25	7	20	1	67	45	205	520

Palo Blanco

	PALO BLANCO												
	Tc 272, F	Tc 50, VI	Tc 272, E	Tc 272, D	Tc 272, C	Tc 272, B	Tc 272, A	Tc 50, V	Tc 254, C'	Tc 254, B	Tc 50, IV	Tc 35e, E	Tc 35e, D
FOOD PLANTS													
Dioon edule		4											
Setaria cf. macrostachya		9.2oz.						3oz.	2oz.		0.5oz.		
Unidentified grass seed		10oz.											
Grass quids	28		109	81	10		3	39	49	139	93		57
Zea mays (maize)	39	2497	186	91	176	105	212	685	134	735	2127	148	1348
Acrocomia mexicana (coyol)	37	46	68	68	18		1	23					1
Amaranthus spp.		544oz.						2oz.		5oz.	33oz.		2oz.
Persea americana (avocado)		85		6				14			15	3	8
Acacia spp.: pods		16							1	23	3		9
seeds													
Acacia sericea: pods									2	32	1		
Arachis hypogaea (peanut)		1											
Canavalia sp. (jack bean)													
Leucaena esculenta	3	4			1		7	3	24	26	22		1
Phaseolus acutifolius (tepary bean)		485											
P. coccineus (runner bean)		1p											
P. lunatus (sieva bean)													
P. vulgaris (common bean)		1						2			1	2	109
Prosopis juliflora: pods		16											
(mesquite) seeds		213oz.						*		27oz.			
quids						6		37	57	10	155		1
Casimiroa edulis (white bean)	3	13	4	3				7		3	4	2	53
Malphigia sp.													
Jatropha neopauciflora	2	28	29	8				5		36	2		
Jathropha sp.										1			
Cyrtocarpa procera (chupandilla)	48	292	923	249	61	54	124	167		1	206	12	1
Spondias mombin (ciruela)	17	19	512	254	24	7	8	4				13	
Condalia mexicana													
Ceiba parvifolia: roots		47				47		6	1		2	4	
(pochote) pods	4	258		3	3	8	24	42	11	26	102	2	1
Cephalocereus hoppenstedtii (tetecho)			1		1					13			1
Escontria chiotilla (jiotilla)								6					
Lemaireocereus hollianus: seed													
stem													
L. stellatus: fruit		4											
L. weberi (cardon): fruit		4											1
Myrtillocactus geometrizans (garambulo)					1	1							
Opuntia spp.: leaves		50	17	10				20		9		12	3
(prickly seeds		*						1oz.					
pear) fruit		203	3				2	16		3			5
Psidium guajava (guava)			4										
Bumelia laetevirens							1			6			
Sideroxylon cf. tempisque (cosahuico)	92	177	30	33		1	4	74		1	438	15	
Diospyros digyna (black sapote)		291						9			11		1
Capsicum annuum (chili pepper)		7									1		
Physalis sp. (tomate)									28	25			
Crescentia cujete (tree gourd)					5					5			2
Unidentified Cucurbita spp. (squashes & pumpkins)		19	1		1			1		5	29	2	24
C. mixta		5	1		1						4	2	3
C. moschata													1
C. pepo										1		12	1
Lagenaria siceraria (bottle gourd)		3						1			1		2
Apodanthera sp.													23
FOOD AND FIBER													
Agave spp.: quids	78	1254	709	201	30	6	16	679	123	295	1479	32	328
leaves	193	1000	1202	388	1045	1369	229	1297	1059	128	1231	24	418
seeds							1oz.			*			
fiber									282oz.	125oz.			
Yucca periculosa: leaves						1	3		3	45			3
seeds			445							2			
FIBER PLANTS													
Brahea dulcis (palm)										18			3
Hechtia sp.								4	1	15	1		
Tillandsia spp.: leaves		7							10	54			1
spikes										22			2
Tillandsia dasyliriifolia		6						2		3oz.	22		
Beaucarnea gracilis (sotolin)		1								31oz.	33oz.		2
Agave kerchovei: stems									1	11			
Cissus sp.	1									2	1		*
Gossypium hirsutum (cotton)	*	2	*	*	*	*	*	*		1	*	*	*
OTHER USES													
Selaginella sp.											1		
Grasses (unidentified)		42						5	3	477	20		2
Agave sp.: spine													
Dioscorea sp.: inflorescence													
Quercus sp.: acorn								1					
Caesalpinia sp.													
Leucaena pueblana: pods										8			
Mimosa sp.: pods		3					1			4			
Jatropha sp.: seed													
Zizyphus pendunculatus (cholulo)			2										
Mammillaria sp. (bisnaga)		4			1	1	3						
Plumeria rubra (frangipani)											1		
Thevetia peruviana										4			
Bark	53	116	86	36	43	57	43	57	4	1	86	1	13
Wood	349	470	644	448	576	856	553	123	142	587	198	25	251

Venta Salada

	VENTA SALADA						
	Tc 35e, C	Tc 255, A	Tc 50, III	Tc 35e, B	Tc 50, II	Tc 50, I	Tc 35e, A
FOOD PLANTS							
Dioon edule	1		2		2		
Setaria cf. macrostachya			2oz.		2oz.	2oz.	1oz.
Unidentified grass seed							1oz.
Grass quids			57	27	58	20	29
Zea mays (maize)	2734	136	4879	1151	2737	1608	1136
Acrocomia mexicana (coyol)	2		5	1	4	4	
Amaranthus spp.	8oz.		78oz.		6oz.		
Persea americana (avocado)	8		7	8	7	3	6
Acacia spp.: pods	1	3	11	4	9	2	5
seeds	16oz.			11oz.			23oz.
Acacia sericea: pods							13
Arachis hypogaea (peanut)					2	2	
Canavalia sp. (jack bean)							
Leucaena esculenta	23	6	17	4	31	1	21
Phaseolus acutifolius (tepary bean)			12p				
P. coccineus (runner bean)	6		1				24
P. lunatus (sieva bean)	1		1				2
P. vulgaris (common bean)	156	?	3	169			41
Prosopis juliflora: pods		8					2
(mesquite) seeds				6oz.	5oz.	35oz.	12oz.
quids	12		13	2oz.	46	2	
Casimiroa edulis (white bean)	66	1	3	17	2	1	19
Malphigia sp.							
Jatropha neopauciflora			8		5	1	
Jathropha sp.			1				
Cyrtocarpa procera (chupandilla)	12		136	17	119	47	31
Spondias mombin (ciruela)	2		25		63	4	2
Condalia mexicana					2		1
Ceiba parvifolia: roots			7		4		
(pochote) pods	8		114	12	125	9	
Cephalocereus hoppenstedtii (tetecho)	3						
Escontria chiotilla (jiotilla)							
Lemaireocereus hollianus: seed							
stem							
L. stellatus: fruit							
L. weberi (cardon): fruit							
Myrtillocactus geometrizans (garambulo)			1		1		
Opuntia spp.: leaves	12	13	69	7	78	10	2
(prickly seeds			1oz.		1oz.		
pear) fruit	14		14	7	19	9	5
Psidium guajava (guava)							
Bumelia laetevirens			1	13			2
Sideroxylon cf. tempisque (cosahuico)	8		58	2	43	9	1
Diospyros digyna (black sapote)	1		3	3	7	1	1
Capsicum annuum (chili pepper)	2			2	1		8
Physalis sp. (tomate)							
Crescentia cujete (tree gourd)	3		3		1	3	6
Unidentified Cucurbita spp. (squashes & pumpkins)	6		108	1	220	254	64
C. mixta		1s	27		42	117	
C. moschata			4	1	26	1	3
C. pepo	10		261	1	1	3	47
Lagenaria siceraria (bottle gourd)	9		15		11	19	8
Apodanthera sp.				125			11
FOOD AND FIBER							
Agave spp.: quids	712	12	765	181	1268	224	242
leaves	607		836	177	976	166	177
seeds				1oz.			
fiber							
Yucca periculosa: leaves	11		5				
seeds					34oz.		
FIBER PLANTS							
Brahea dulcis (palm)	11						
Hechtia sp.						2	
Tillandsia spp.: leaves	4						
spikes	24				2		
Tillandsia dasyliriifolia			1		14		
Beaucarnea gracilis (sotolin)	10		1		1	1	
Agave kerchovei: stems							
Cissus sp.	2				2	1	
Gossypium hirsutum (cotton)	*		*	2	*	*	*
OTHER USES							
Selaginella sp.							
Grasses (unidentified)	9		8		33	2	
Agave sp.: spine							
Dioscorea sp.: inflorescence							
Quercus sp.: acorn							
Caesalpinia sp.							
Leucaena pueblana: pods					3	4	
Mimosa sp.: pods			5		3	4	
Jatropha sp.: seed			1				
Zizyphus pendunculatus (cholulo)			1		42	1	
Mammillaria sp. (bisnaga)					1		
Plumeria rubra (frangipani)							
Thevetia peruviana	1						
Bark	117		94	45	126	36	16
Wood	316		648	222	492	143	117

*Quantity to small to measure. f Flower. p Pod. s Seed. w Wild.

mon bean pod (*Phaseolus vulgaris*) found in Zone XI is the earliest bean specimen from the Tehuacan excavations. A fragment of chili pepper was found in each of the three zones.

Plants common to the native vegetation form a far larger bulk of materials in the Coxcatlan phase than do remains of the corn-squash-bean-chili complex. Maguey quids and leaves appear in amounts numbering in the hundreds, and the quantities of setaria and grass seed remain large. Pochote pods are present in increasing numbers, along with fragments of the edible root. Seeds of mesquite, *Jatropha neopauciflora*, and prickly pear and other cacti are well represented.

A variety of fruit remains are present in the three Coxcatlan phase zones, some of them in really large amounts, as the accompanying figures shows. Added to the four previously popular fruit species—chupandilla, avocado, ciruela, and cosahuico—are three new ones: coyol (*Acrocomia mexicana*), white sapote (*Casimiroa edulis*), and black sapote (*Diospyros digyna*).

	Zone XIII	*Zone XII*	*Zone XI*
Avocado	0	1	32
Chupandilla	22	78	1159
Ciruela	5	0	4
Cosahuico	5	11	271
Coyol	0	4	7
White Sapote	0	0	4
Black Sapote	0	0	2

Although remains of these new species are not yet numerous, their appearance is significant. These plants could not grow in the Tehuacan region without supplementary water, and the appearance of all three in Zone XI indicates that the Coxcatlan phase people had managed to control the water available and supply it to plants which were desirable but were by no means dietary necessities. Evidence of the progress of these people as agriculturists may also lie in the vast number of chupandilla seeds recovered—1,159 in Zone XI alone—which show an interesting range of sizes, perhaps indicative of experiments with cultivation.

The Coxcatlan phase people, then, were growing an increasing number of cultivated plants, both annual and perennial, but the bulk of the plant material still came from a variety of native species. It is probable that some of the latter, such as maguey and prickly pear, were being cultivated too. The plant materials as a whole from Zones XI–XIII indicate that a large number of people were occupying the caves, with an increase in number from the earliest zone to the latest. Among the diverse plant materials present are indications of occupation in the spring, summer, and fall months.

The next three levels, Zones X, IX, and VIII, represent the Abejas phase of about 3500 to 2300 B.C. Plant parts are fewer in number, although a variety of species are present, including fragments of such cultivated plants as maize, squash, beans, and chili peppers. Besides one pod each of common bean and *Canavalia* sp., there were a total of 118 tepary beans (*Phaseolus acutifolius*). However, the proportion of maguey, prickly pear, and pochote remains to remains of maize and other annual plants is significantly greater. Fruit remains are also proportionally less plentiful. The seven species represented in the Coxcatlan phase levels are present here, with an increase to fifty black sapote seeds in Zone IX the most notable occurrence.

Pochote pods and fragments of the cacti, cardon and xoconochtle, indicate spring residence in these zones, and mesquite seeds show summer, and assorted fruits fall to early winter occupation.

Coxcatlan Cave was not occupied in early Formative times. There is a gap of at least two thousand years between Zone VIII and Zone VII. The latter represents the latter part of the Santa Maria phase, which extended from before 900 B.C. to about 200 B.C. The most significant change to be noted in the plant materials of this level is the slight predominance of maize (580 cobs), squash, and cultivated fruits over maguey, pochote, prickly pear, mesquite, and other plants representative of the native vegetation. Much of the maguey, however, may have been cut from permanent plantings.

Besides maize, squash, and gourds, there was a single runner bean (*Phaseolus coccineus*) in Zone VII, as well as a few fragments of chili pepper, one ounce of amaranth (probably cultivated), and two cotton plant fragments. From Santa Maria times on, cotton remains appear consistently, along with cloth woven from cotton fiber. Also present in Zone VII, even after maize has become the staple grain, are 6.5 ounces of setaria and grass seed. Although these seeds never again appear in the large quantities in which they were recovered from the El Riego and Coxcatlan horizons, they persist in smaller amounts through Zone I. They were a source of food in the valley for some 8000 years, even though their role in the diet shifted drastically after corn was domesticated.

Among the fruit remains in Zone VII were 35 avocado, 979 chupandilla, 57 ciruela, 166 cosahuico, 6 coyol, 7 white sapote, and 13 black sapote seeds. Most of the fruits indicate fall and early winter occupancy. Pochote pods, a single tetecho fruit, and mesquite and

Jatropha neopauciflora seeds show that the cave was occupied in the spring and summer as well.

Zones VI, V, and IV are assigned to the Palo Blanco phase, dating from about 200 B.C. to A.D. 700 or 800. Maize remains number in the thousands in these levels, as do both quids and leaves of maguey. Squash and gourd specimens are present but not numerous. Bean species are represented by 485 tepary beans and a runner bean pod in Zone VI and a few common bean seeds in all three levels. The large peanut seed in Zone VI, the earliest fragment of *Arachis hypogea* recovered, is obviously from a cultivated strain. Some of the huge amounts of amaranth recovered from Zones IV and VI were found in large storage pits. The common fruits again make up a substantial portion of the plant material in these zones, as the accompanying tabulation shows.

	Zone VI	*Zone V*	*Zone IV*
Avocado	85	14	15
Chupandilla	292	167	206
Ciruela	19	4	0
Cosahuico	177	74	483
Covol	46	23	0
White sapote	13	7	4
Black sapote	291	9	11

All the usual plant products representative of the native flora appear in the earlier two Palo Blanco zones, but the cactus species—notably *Opuntia*—are absent from Zone IV. The various zones were occupied in the spring, judging from the pochote pods in each. Mesquite remains and *Jatropha neopauciflora* seeds show summer occupancy, and fall-ripening fruits indicate fall to early winter residence. Perhaps these zones represent visits by groups of agricultural workers through the growing and harvesting season.

The three upper levels of the cave, Zones III, II, and I, date from the Venta Salada phase of before A.D. 800 to about 1540. Maize cobs in these zones are more numerous than in the Palo Blanco zones. Maguey quids and leaves once again appear in huge quantities, but in these levels do not equal the quantity of maize remains. The various cucurbit species are well represented. Beans are rare—one small lima bean and two common beans in Zone III are the only specimens. Guaje (*Leucaena esculenta*), a tree legume which may have been cultivated, is substantially represented. It has been consistently present since Zone VII and appears sporadically before that. Peanuts appear again in Zones I and II, amaranth in Zones II and III, and setaria in small quantity in each zone.

The fruits, as usual, make up a large share of the plant materials, but they are not as numerous in relation to the maize and maguey remains as formerly. Chupandilla seeds are the most plentiful, as the accompanying tabulation shows.

	Zone III	*Zone II*	*Zone I*
Avocado	7	7	3
Chupandilla	136	119	47
Ciruela	25	63	4
Cosahuico	58	43	9
Covol	5	4	4
White Sapote	3	2	1
Black Sapote	3	7	1

Among plants parts which can serve as seasonal indicators, pochote pods indicate spring occupancy of all three zones, seeds of mesquite and *Jatropha neopauciflora* show summer residence, and fruit remains are evidence of fall and early winter occupancy.

The plant materials recovered from twenty-four zones of Coxcatlan Cave document man's utilization of the botanical resources of the Tehuacan Valley and his acceptance of introduced plants as additions to his diet. From a seed of mesquite, a fragment of palm leaf, and two clumps of grass in Zone XXVI, the plant remains increased in quantity, quality, and variety to include thousands upon thousands of fragments representing well over fifty species. Among the remains are the results of man's first experiments in agriculture, but no one fragment can be singled out as proof of the beginning of agriculture. The early inhabitants transplanted fruit trees to more accessible locations and, in their cultivation, discovered that selection of better propagules increased productivity. They probably cultivated setaria, and they undoubtedly learned that maguey and prickly pears could be grown easily by vegetative propagation. The first steps toward agriculture were probably made during the El Riego phase, for in the subsequent period very definite products of agriculture—cultivated squashes, the common bean, early forms of maize, fruits needing cultivation for survival—all appear, though in very small numbers compared with the amount of material gathered from wild species. From Coxcatlan times on the remains from the cave present a history of the enlarging cultivation of food and fiber plants.

Description of the Plant Remains

The plant remains posed few problems in identification, since there had been no major change in the flora and, consequently, no change in the plants available to the local populations. Fortunately, the pattern of dietary preferences discernible today is the modern

equivalent of the preferences deduced from the archaeological material. Local men working for the Tehuacan project were able to make tentative identifications of many obscure fragments, which upon comparison with known material proved to be correct. For this expert help, I am very grateful. As with the debris in any junk pile, some fragments defy identification, principally because the plant parts necessary for classification are missing. As groups of which this is particularly true are discussed, the fact will be noted. Because it is easier to make comparisons when related plants are discussed together, the order of discussion will be that set down in the Engler and Prantl system of family arrangement.

Selaginellaceae (Club Moss Family)

Selaginella sp. (resurrection plant; helecho). Basal portions of two plants were found in Coxcatlan Cave, Zones VII and IV (Santa Maria and Palo Blanco phases). The fragments were too incomplete to identify specifically. The local flora today includes the resurrection fern, *S. lepidophylla*. The two specimens were probably casual intrusions. No local uses or superstitions connected with this plant were discovered, nor does Martinez (1928) mention any use for *Selaginella*.

Cycadaceae (Cycad Family)

Dioon edule Lindl. (chamal: Martinez 1937). The broken seed coats of this plant were not abundant, but showed that the plant had been fairly persistently used over some thousands of years, primarily by the occupants of Coxcatlan Cave (see Table 26). The only other find of this plant was one fragment of seed coat in the East Niche of El Riego Cave, Zone D (Palo Blanco). Today *Dioon* trees do not grow near any of the archaeological sites, nor do local people seem to know the plant. I saw a few trees on slopes above Teotitlan del Camino, Oaxaca, near the edge of the oak and pine forest where precipitation is somewhat greater than in the thorn-scrub-cactus forest in the valley below. Farmers plowing a nearby field used the name "palmilla," but said they knew of no use for the plant. The oblong seed, about 2.0 by 3.5 cm., provides a starch food when cooked, but it could never have been important in the diet of the Coxcatlan Cave people. The cones and foliage are known to be poisonous to animals, and the seeds might once have been considered medicinal.

Gramineae (Grass Family)

Chloris virgata Sw., *Heteropogon contortus* (L.) Beauv., *Trichloris pluriflora* Fourn. (grass; pasto).

Fig. 138. *Dioon edule* growing on the mountain slope above Teotitlan del Camino.

Fig. 139. Cone of *Dioon edule*, in which edible seeds are borne.

Grass brought into the caves, perhaps for padding or bedding, was sometimes found in large amounts. Generally, it was impossible to identify the species of grass involved, because critical decisions depend upon characters of the mature inflorescence. The above species were identified from inflorescence fragments culled from some of the masses of grass.

A number of grass quids, consisting of chewed stalks, were also found. The various grasses were probably gathered from expanses which must have developed across open areas during the wet season. Today herds of sheep and goats keep the grass well trimmed.

Fig. 140. Fruit of the coyol palm *(Acrocomia mexicana)*, Tc 50, Zone III, actual size.

Fig. 141. Leaf of the palm *Brahea dulcis*, Tc 254, Zone B (x 0.6).

Unidentified grass—stems only (reeds, grass; carrizo, pasto). Numerous fragments of grass stems split to various degrees are obviously discards from the manufacture of baskets or other items. A few cut sections of cane were charred on one end as though they might have been used as cigarettes, but no charred leaf material was found inside to constitute absolute proof. The stem sections and split fragments are not complete enough to identify. They are probably stems of *Phragmites communis* Trin. Today, irrigation ditches of the Tehuacan area are frequently lined by masses of *Arundo donax* L., locally called "carrizo," but a comparison of the archaeological material shows that the ancient specimens are not this species. *Arundo* is definitely a post-Conquest introduction.

Setaria cf. *macrostachya* HBK. (pasto). Seed of this species was found in most levels of Coxcatlan Cave, in caches or abundantly through the fill. They were also present in two levels of San Marcos Cave. The small yellowish to brown caryopses are about 2 mm. long and 1.2–1.5 mm. wide, flattened on one side and curved and rugose on the other. Sometimes they were found still attached to small fragments of bristly inflorescence. Nowadays, this species is not common in the valley, but it may once have been abundant along arroyos and on alluvial fans, together with other grasses. Under good conditions, the culms may reach a height of a meter with a panicle of fruit as long as 25 cm. A native of North America, this grass grows as far north as the southwestern United States.

Analysis of the pieces of inflorescence caught up with the seed reveals that inhabitants of the cave winnowed the seed by rolling the heads of grass between the palms of their hands. From the seed found in the deposits, no method of preparation can be ascertained, but it is obvious that grass and setaria seed constituted an important dietary item in El Riego and Coxcatlan times. The seed persisted to the top of the deposit in Coxcatlan Cave as a supplementary food.

Zea mays L. (corn; mais). Maize was an important crop in the Tehuacan Valley from the Coxcatlan period on. The material recovered is analyzed above in Chapter 9.

Palmaceae (Palm Family)

Acrocomia mexicana Karw. ex Mart. (coyol). Coyol palm fruits are a commonplace item in the deposits of Coxcatlan and Purron caves from Coxcatlan times on. Some fragments also appeared in late levels of the East Niche of El Riego Cave. From the appearance of the fragments, both the outer fleshy portion and the inner seed were used. The outside of the pieces is usually devoid of flesh, and the bony endocarp is irregularly broken. The coyol is still used locally as a fleshy fruit for eating out of hand and, in some parts of its range, for the manufacture of wine. Coyol is found nowhere today in the Tehuacan region as a natural wild plant and therefore must have been a cultigen in prehistoric times.

Brahea dulcis (HBK.) Mart. (palm; palma). This palm is the source of leaf fibers presently used for the manufacture of hats in the area west of the Tehuacan Valley. The fruits are sweet and edible, but no fruit remains were recovered. Small amounts of leaf fragments were found in El Riego, San Marcos, and Coxcatlan caves, and a single fragment of leaf was among the very earliest remains from Coxcatlan. The sparseness of material probably indicates few locally available sources or a preference for other kinds of fiber. The lack of fruit remains strengthens the opinion that few *Brahea* trees grew near the cave sites.

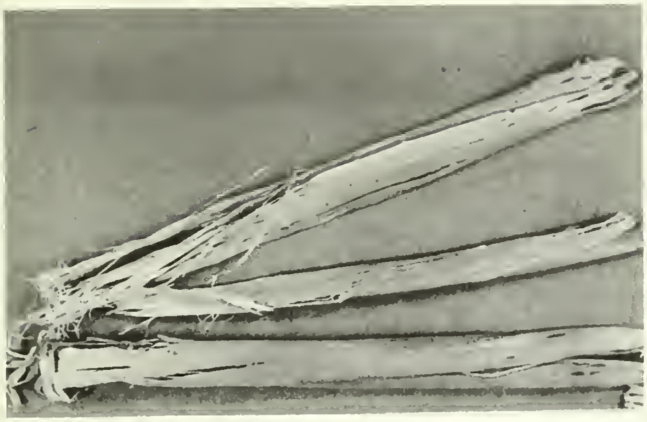

Fig. 142. Leaves of soluchil *(Tillandsia* sp.) from which the outer layers have been stripped. The ends were being worked into fiber when the piece was discarded in San Marcos Cave (x 0.6).

Bromeliaceae (Pineapple Family)

Hechtia sp. Colonies of spiny *Hechtia* sprawl across the dry slopes near all of the cave sites. They offer a ready supply of leaves which, like many species of the Bromeliaceae, have tough fibers. The leaves are not very long and are stoutly armed with sharp spines, which must have made unpleasant the gathering and processing of them for fibers. For the same reason, though, the leaves would probably not have been casually gathered for discard in the caves. Small amounts of leaves were found in Abejas, Santa Maria, Palo Blanco, and Venta Salada zones of Coxcatlan or San Marcos caves.

Tillandsia spp., including *T. dasyliriifolia* Bak. (air plant; soluchil). Leaves of several species of *Tillandsia* were present in Coxcatlan Cave from Coxcatlan levels on and in more recent levels of San Marcos and El Riego caves. The native species in the valley have a heavy layer of scurfy scales on their leaves, which the people apparently managed to remove. If my interpretation of the recovered fragments is correct, the inner leaf tissue was then rolled into quills and worked (perhaps by chewing) into soft fibrous material. The plants were probably brought into the sites whole, and then were divided into individual leaves, for several pieces of inflorescence were also found in Palo Blanco and Venta Salada levels.

Tillandsia usneoides L. (Spanish moss; paxtle). Small amounts of Spanish moss were found in the deposits, perhaps brought from nearby moist barrancas or from oak and pine forests farther up the mountain slopes. I

Fig. 143. Sotolin *(Beaucarnia gracilis)* near Zapotitlan. The leaves, when dried and split, furnish a very tough fibrous material.

could find no evidence that this material was being used for fiber. Since present-day Mexicans use Spanish moss to decorate arches and other structures for fiestas, the plant possibly had religious significance for earlier peoples.

Liliaceae (Lily Family)

Beaucarnea gracilis Lem. (sotolin). Sotolin grows on the well-drained soil overlaying limestone on the western side of the Tehuacan Valley. It was probably once quite abundant, but reproduction is apparently slow (I have seen no evidence of seedling plants even in areas in which fruiting trees are usual). The leaves are tough and were probably a source of fiber. The earliest record for this plant is four leaf fragments in Tc 50, Zone XI (Coxcatlan). Other foliage fragments were infrequent.

Fig. 144. Izote *(Yucca periculosa)* in bloom in March at San Marcos Cave.

Yucca periculosa Bak. (yucca; izote). Izotes serve many purposes in present-day Mexico. The flowers and fruits of some species are edible, and a liquor is fermented from the tissue inside the trunk of at least one kind. Many izotes have usable leaf fibers. The spongy tissue inside the trunk of some species is used for padding under the saddles of pack animals. The local izote was and is still used by the people of the Tehuacan Valley. Fragments of izote leaves were more plentiful in the later levels of the deposits, and in some levels quantities of seeds were present.

Amaryllidaceae (Amaryllis Family)

Agave spp. (century plant; maguey). Maguey plants furnished a major portion of the raw materials needed by the early people of the Tehuacan Valley. Chewed leaf tissues in the form of quids indicate that maguey was a large item in the diet in all periods and a major item in the earlier levels. Numerous leaf fragments, spine tips, and other plant parts show that the plant was put to many uses.

Unfortunately, species of *Agave* are difficult to distinguish unless there are ample leaf fragments with intact margins and tips and, frequently, flowers or fruit. Only a few of the recovered fragments could be identified to species. These are: *Agave* cf. *karwinskii* Zucc.

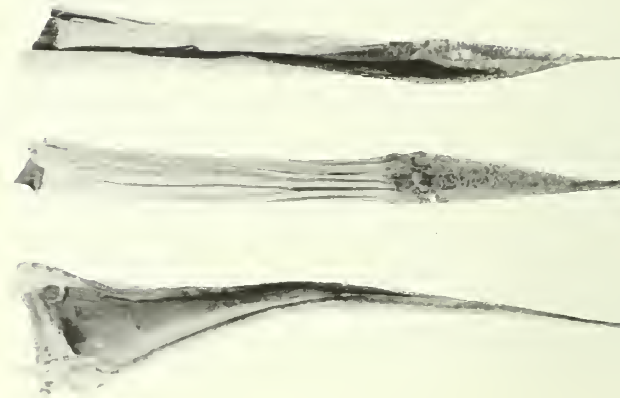

Fig. 145. Charred spines of maguey *(Agave ghiesbreehtii)* from Tc 254, Zone F, actual size.

leaf tip spine, Tc 272–A, 1 (Palo Blanco); *Agave kerchovei* Lem. (rabo de leon) stem fragment, Tc 254–B, 11, and Tc 254–C[1], 1 (Palo Blanco), *Agave* cf. *ghiesbrechtii* Koch, leaf tip spines, Tc 254–B, 5, and Tc 254–C[1], 5; Tc 50–VI, 1 (Palo Blanco); Tc 254–D, 1 (Abejas); Tc 50–XIV, 1 (El Riego).

The frequency and distribution of the maguey remains lead me to believe that the people of Coxcatlan and Purron caves in later periods may have been drawing upon maguey plantings for the uses for which they were putting the plant. Consumption of maguey leaves (baked?) was high in both caves. The numbers of fragments of maguey leaves in the two caves and the finding of fiber material in San Marcos Cave may indicate a fiber industry among these people. They may well have supplied fiber or finished woven articles used by other people.

Infloresence material of certain species of maguey was present because the flowers were used as food. Although the plant remains do not demonstrate the existence of an *agua miel* or pulque industry among these people, it seems safe to assume that some among them discovered that drinking the fermented sap was a pleasant experience.

Besides the thousands of leaf fragments and quids recorded in the tables, the following amounts of fiber were recovered: Tc 254–B, 125 oz.; Tc 254–C[1], 282 oz. (Palo Blanco); Tc 254–C, 10 oz. (Ajalpan); Tc 254–D, 44 oz. (Abejas).

Dioscoreaceae (Yam Family)

Dioscorea sp. (yam). One fragment of inflorescence, with dehisced seed pods adherent to it, was identified as *Dioscorea*. The fragment may have fallen from a

piece of vine used to tie a bundle. Certainly, no other evidence indicates that the people of the Tehuacan Valley knew or used edible yam tubers. The *Dioscorea* specimen, found in Tc 50–VII (Santa Maria), must be an accidental intrusion.

Fig. 146. Inflorescences of amaranth with seeds removed, Tc 50, Zone VIII, actual size.

Fagaceae (Oak Family)

Quercus sp. (oak; roble). Three acorns were found, one in Tc 50–V (Palo Blanco) and two in Tc 50–XI (Coxcatlan).

Amaranthaceae (Pigweed Family)

Amaranthus cf. *cruentus* L. and *A.* cf. *leucocarpus* Wats. (pigweed; quelite). Remains of *Amaranthus* spp., sometimes in large quantities, were found in Coxcatlan, El Riego, San Marcos, and Purron caves. The history of the ceremonial use of amaranth (frequently called "alegria" or "bledo") has been told in detail by Jonathan Sauer (1950). It was undoubtedly used for religious purposes in the Tehuacan area. However, amounts of amaranth seed and inflorescence material recovered from Coxcatlan Cave suggest that the plant was also a part of the diet of the people living there. The earliest remains date from the El Riego phase. Workmen helping with the excavation of the caves commonly used the name "quelite" for the *Amaranthus* fragments, although this name is probably more usually applied to the weed amaranth, not to the cultivated species whose seeds are used for food.

Lauraceae (Laurel Family)

Persea americana Mill. var. *drymifolia* (Schlecht. and Cham.) Blake (avocado; aguacate). Remains of avocados came from almost all levels of Coxcatlan Cave, beginning with Zone XXIV of the Ajuereado phase. Seeds of this fruit were present in upper levels of other caves also. Variation in the size of the fruit of avocado

Fig. 147. Avocados *(Persea americana)*. *Left,* pit from Tc 50, Zone XVIII; *center,* two pits from Tc 50, Zone VII; *right,* a fruit of the anise-flavored Mexican race (var. *drymifolia*) purchased in the Tehuacan market. All x 1.5.

is normal, as it is for most plants. However, fruit collected from native wild trees is consistently small. Because the seeds vary in shape as well as size, the average size of wild avocado seeds is best expressed as an index figure derived from multiplying the length in cm. by the width in cm. For dried seeds of wild-type fruit from the Tehuacan market $l \times w = 3.47$. Whenever the size of dried seeds falls outside the usual range, it is apparent that selection for larger fruit is being undertaken.

In the deposits in Coxcatlan Cave, small seeds similar to those from present-day native trees are found in Zones XXIV ($l \times w = 4.62$) and XVIII ($l \times w = 6.48$), both of which are based on measurements of single cotyledons. The only intact cotyledon of the eight from Zone XVIII is the largest found in this level. In the Coxcatlan horizon, two measurable cotyledons yield $l \times w = 3.40$, and in the Abejas horizon, two cotyledons show $l \times w = 3.78$. In the Santa Maria horizon, a definite increase occurs ($l \times w = 7.80$, based on nineteen cotyledons), but it should be noted that the small cotyledons persist, the smallest being 1.4 x 1.5 ($l \times w = 2.10$). The size of the cotyledons increases greatly in the Palo Blanco phase ($l \times w = 10.50$) and decreases slightly in the most recent Venta Salada horizon ($l \times w = 9.92$). Even in the latest horizon, though, the small wild-type avocado is found (the smallest measured, $l \times w = 2.55$).

Several facts are evident concerning avocados. The other vegetal remains indicate that the climate of the area has remained unchanged from at least the beginning of El Riego time to the present. Under this rainfall regimen, avocado cannot grow naturally in the valley nor on the lower slopes of the mountains. Avocado is a thin-foliaged tree of the mesic forests of the barrancas higher up the mountains. The earlier cotyledons must have come from fruit gathered from the barranca forests. These mesic forests probably never extended to the lower areas where the sites are located, since so few products from plants native to the barranca environment—such as *Inga, Piper, Ficus,* and *Peperomia*—are present among the remains.

It is obvious that the avocado was brought into cultivation in the Tehuacan Valley. A major increase in fruit size would not occur in wild populations of avocado trees. The marked increase in size of seeds found in the Santa Maria horizon can be attributed only to active selection of larger and better fruit for propagation. The act of selection presupposes that the cultivation of avocado had been sufficiently well established so that the valley people knew they would be successful when they planted avocado seeds. It further indicates

Fig. 148. Peanuts *(Arachic hypogaea). Left,* seed from Tc 50, Zone VI; *right,* fragment of shell from Tc 50, Zone I. Both actual size.

that they recognized their success with selection in other crops, such as maize. With the latter crop planted annually, results of selection become apparent within a very few years. Selection in a tree crop is tediously slow to produce results for several reasons. Pollenation in mixed groves of avocados is open and the chances of a large-fruited tree being pollenated from another large-fruited tree are very tenuous. Further, the seedlings of selected large-fruited forms would not reach bearing size for at least seven years after planting and young trees would not produce fruit of maximum size until they had been bearing for several years. Thereafter, the large-fruited selections would be genetically swamped by pollenation by small-fruited, wild-type trees in the area. Thus, it must have taken a very long time before the size increase due to selection became apparent in the cotyledons being deposited in the caves, particularly since all fruit available would be harvested for use irrespective of size.

Cultivation of avocados also implies water control in the valley, inasmuch as avocados cannot exist in the valley over the long dry season. Perhaps the best evidence for a form of irrigation is the sudden appearance of coyol and black and white sapotes among the remains from Zone XI (Coxcatlan phase) of Coxcatlan Cave. Because of its obvious popularity, avocado must have been under irrigation cultivation also and lessons learned in the successful cultivation of avocado may have paved the way for the introduction of other fruit trees needing supplementary water.

Leguminosae (Pea Family)

Acacia sp. and *A. sericea* M. & S. (guaje). Fragments of *Acacia* pods were frequent in Coxcatlan Cave, but they were seldom distinctive enough to be identified to species. Some pieces were also recovered from San Marcos Cave. The green pods were probably eaten whole, although present inhabitants of the area consider them inedible. A few of the pods are definitely fruit of *A. sericea,* locally known as "guaje blanco." The

earliest *Acacia* specimens appeared in the Coxcatlan phase.

Arachis hypogaea L. (peanut; cacahuate). Peanuts were found only in Tc 50, Zones I and II (Venta Salada phase) and VI (Palo Blanco). The size of the fragments leaves no doubt that these were remains of fully cultivated plants. The single seed from Zone VI is large when compared with modern peanuts. This plant is not native to the Tehuacan region.

Caesalpinia velutina (B. & R.) Standl. (guaje). The single pod fragment of this species, from Tc 254–D (Abejas), is probably an accidental introduction.

Canavalia sp. (jack bean). Remains of this and *Phaseolus* spp. are described above in Chapter 10.

Leucaena esculenta (M. & S.) Benth (guaje). This variety of guaje is presently widely cultivated and appears to be a regular dietary item among the Indian people of the Tehuacan Valley. The green pods, the guaje proper, are used when available. When the trees are not fruiting, small galls called "polochoco" are gathered from them and boiled to be eaten. Fragments of pod and seed were found as early as the El Riego phase of Coxcatlan Cave, and they appear fairly consistently in that site. A few remains were found in Purron Cave and a moderate number in San Marcos Cave.

Leucaena pueblana B. & R. (guaje). Pod fragments were found in a few Venta Salada and Palo Blanco levels. It is not certain that they were used as a food, but a total of 15 fragments probably are not an accidental intrusion.

Mimosa sp. A few fragments of pods came mainly from Venta Salada and Palo Blanco zones. Two specimens came from the Abejas phase of San Marcos Cave.

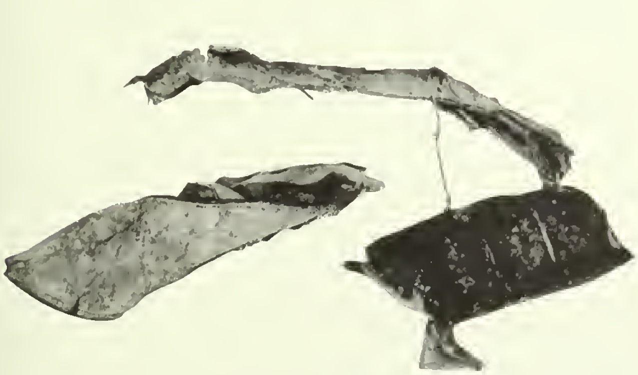

Fig. 149. Pods of *Leucaena esculenta* from Tc 254, actual size.

Fig. 150. A cache of seeds of mesquite *(Prosopis juliflora)* from Coxcatlan Cave.

Fig. 151. Chewed quids of mesquite, from Tc 254, actual size.

Prosopis juliflora (Sw.) DC. (mesquite). Remains of mesquite, primarily in the form of seeds, appeared in considerable abundance in the deposits. Chewed pods constituting quids and whole pods were also discovered. Mesquite remains come from the earliest level at which there was preservation and continue to the top of the deposits. This plant obviously furnished one of the regular items of the prehistoric diet. During later times, when techniques of cultivation were well known, mesquite may have been cultivated, although the remains show no morphological evidence of this. At the present time, fruit is harvested from wild trees as well as from cultivated trees in the Tehuacan Valley.

Rutaceae (Citrus Family)

Casimiroa edulis Llave & Lex (white sapote; zapote blanco). Zapote blanco or zapote duermelon is cultivated for its fruit. It is one of the plants whose remains in the Tehuacan excavations are indicators of some

Fig. 152. Seeds of chupandilla *(Cyrtocarpa procera)* from Tc 50, Zone XIII, actual size.

Fig. 153. Chupandilla fruit, with dried flesh and broken seeds, Tc 50, Zone II, actual size.

kind of water control in the valley. It cannot survive in the Tehuacan climate outside of cultivation. Because it has to be cultivated, and the fruit is a supplemental rather than an essential item in the diet, its appearance in the deposit is significant.

Had there been some change in the species composition of the plant remains which could be interpreted as having been caused by a climatic change or a permanently higher ground water level in the past, the appearance of white sapote could be accepted as a possible component of a more mesic forest in the area. Because the indications are otherwise, species among the remains requiring a more mesic environment—for instance, white sapote, black sapote, coyol, avocado, and ciruela—are evidence that local agriculturists were aware of the conditions under which they could be grown and had sufficient knowledge of irrigation techniques to be able to furnish water for these plants during the dry season.

Although there is variation in the sizes of the seeds, the fragments of fruit and the seeds do not show any clear indication of selection for larger fruit in the upper levels of the deposit, in marked contrast to fruit trees like avocado.

White sapote remains appear regularly but rarely in large numbers in the middle and upper zones of Coxcatlan, El Riego, and Purron caves. Because each fruit has a number of seeds, the excavated sample may represent fewer whole fruits than do remains of single-seeded species. The largest number of seeds recovered was sixty-six in Zone C of the East Niche of El Riego Cave, a Venta Salada component.

Malpighiaceae (Malpighia Family)

Malpighia sp. (nanche). Nanche, the fruit of at least two species of *Malpighia* in the Tehuacan area (the name is applied to *Byrsonima crassifolia* in other parts of Latin America), is locally collected today, but only one fruit, from Zone XIII of Coxatlan Cave, was identified among the plant remains. No seeds were found.

Euphorbiaceae (Poinsettia Family)

Jatropha neopauciflora Pax. Seeds of this species are conspicuous in the deposits from the earliest to the latest levels. Since the seeds are never cracked, but clearly show the marks of rodents' teeth whenever they are found open, the seeds were apparently not used by the gatherers. From the abundance of these seeds, though, it is obvious that some portion of the plant, probably the foliage, constituted one of the regular dietary items. Most of the seeds appear in Coxcatlan and Purron caves, but one collection represents the Palo Blanco phase of San Marcos Cave.

Jatropha sp. In addition to the nearly spherical seeds of *Jatropha neopauciflora*, two seeds of another species with a three-seeded capsule were found: one in Tc 50, Zone III (Venta Salada), and one in Tc 50, Zone VII (Santa Maria). Foliage of the plants from which these two seeds came may also have been eaten as greens, but the seeds probably were accidental intrusions or were for medicinal use. Many of the *Jatropha* species are known to have a cathartic principle in the seeds.

Anarcardiaceae (Poison-ivy Family)

Cyrtocarpa procera HBK. (chupandilla). Chupandilla occurs in the Tehuacan Valley as a native member of the thorn-scrub vegetation. A tree growing only to 6 or 8 m. in height, it has a twisted trunk, gray bark, and up to about seventeen leaflets to each compound leaf. The fruit is pubescent and said to have a resinous flavor, but it is used where it occurs from Jalisco to Puebla and Oaxaca. It is not a prominent member of the Tehuacan thorn-scrub, usually growing as scattered individuals. According to Miranda (1948), the bark is a substitute for soap.

Fig. 154. Fruit of ciruela *(Spondias mombin)* from Tc 50, Zone XIII.

One seed of chupandilla was present in Zone XXIV of Coxcatlan Cave (Ajuereado phase), and from the El Riego phase on the seeds were present in increasing quantity, in all but one instance outnumbering the remains of any other fruit. In Purron Cave the seeds appeared sporadically at first, beginning with Zone R (El Riego phase), and they increased from Santa Maria levels on; the largest number from a single level of this cave was 923 in Zone E (Palo Blanco phase). Chupandilla seeds were much less common in the East Niche of El Riego Cave, and only one seed was recovered from San Marcos Cave, from a Palo Blanco level. An analysis of the seeds show a subtle but definite increase in size through time. Seeds measured for length and width (in cm.) averaged (l x w) 2.31 in Zone XI of Coxcatlan Cave. Seeds from Zone III of the Venta Salada phase of the same cave had the largest average, 3.09.

Spondias mombin L. (Spanish or hog plum; ciruela). Ciruela is another of the fruits which do not grow as a part of the native vegetation of the Tehuacan area. It is susceptible to frost injury as well as requiring more, and more evenly distributed, rainfall than is found in the valley. Once well established, ciruela trees will persist under somewhat drier conditions than avocado, but in the Tehuacan region they cannot grow unless they are tended and irrigated.

Again, the question arises as to the effect of a higher ground water level in the area in earlier periods. At the present time, the tree is apparently not persistent outside of cultivation anywhere in the region of the upper Papaloapan drainage, since it is not mentioned by Miranda (1948). Even in the frost-free lower reaches of the region, then, rainfall is not sufficiently well distributed during the year to enable ciruela to grow naturally. None of the information available from the plant remains indicates that the dry period was ever shortened so that an elevated ground water level persisted year-round during the time represented by the deposits. Furthermore, no vegetational change occurred suggestive of a warmer climate which would enable ciruela to grow in the upper reaches of the valley.

Fig. 155. Cotton *(Gossypium hirsutum)*. *Above:* "wild"-type bolls: *left*, from Cape Sable, Florida, and *right*, from Tc 50, Zone V. *Below: left*, segment of large boll from Tc 50, Zone XVI, and *right*, from the cultivar Deltapine grown at Stoneville, Mississippi. All approximately actual size.

Because the ciruela does not grow in the valley as a native member of the thorn-scrub flora, the oldest find of ciruela seeds is highly significant. A lot of 200 seeds from Zone XVI of Coxcatlan Cave (El Riego phase) indicates a nearby source of fruit, since this is not a primary food item, but a secondary food which contributes variety without furnishing essential food values not obtainable from other foods. Chupandilla, which ripens later in the year, is a similar fruit in size and flavor.

Rhamnaceae (Buckthorn Family)

Condalia mexicana Schlecht. Seeds of *Condalia* are found in the early levels of Coxcatlan Cave, reach maximum abundance in the intermediate zones, and fall off in number in the upper levels. They are not present in other excavations. The fruits are small, bright red, and edible. One species of *Condalia* yields a blue dye, and the root bark of several species is a soap substitute. The shrub is a member of the native thorn-scrub complex.

Zizyphus pedunculatus (Brandg.) Standl. (cholulo). Cholulo is a native of the thorn-scrub vegetation and is gathered locally for the saponin content of the fruit, which is said to be particularly good for washing the hair. Seeds of cholulo appear scantily in the upper levels of Coxcatlan and Purron caves.

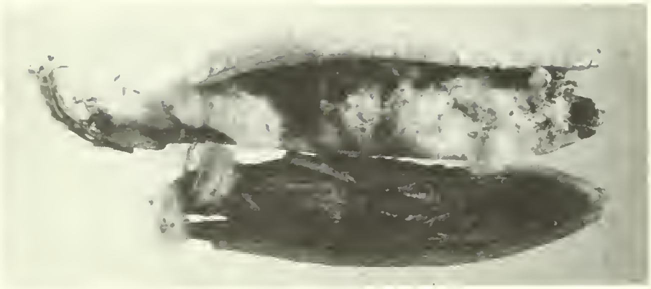

Fig. 156. Pochote pods from Tc 254, x 0.6.

Fig. 157. Pochote fiber used to enclose what may have been a paste of ground seeds, Tc 50, Zone III, actual size.

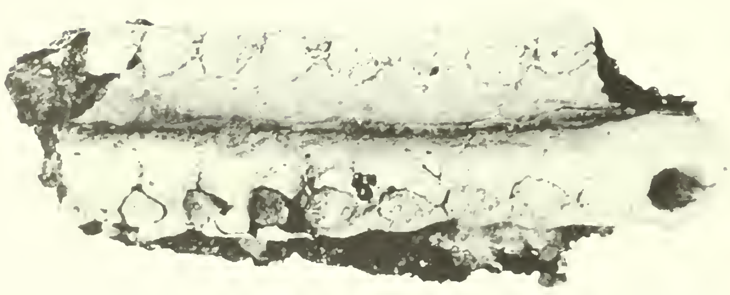

Fig. 158. Fragment of stem of *Lemaireocereus hollianus* from Tc 50, Zone XVI, actual size.

Vitaceae (Grape Family)

Cissus sp. A number of stem fragments apparently of this genus were found with marks of usage which suggested that the stems were used whole for tying bundles and were sometimes pounded to obtain the rather harsh fiber. The earliest fragment appeared in an El Riego level of Coxcatlan Cave. Fragments were found in later levels of that cave and in Purron and San Marcos caves.

Malvaceae (Mallow Family)

Gossypium hirsutum L. (cotton; algodon). Cotton is well represented in the excavations by artifacts ranging from small bits of string to sizable pieces of fabric. The artifacts are primarily from the Palo Blanco and Venta Salada horizons, but some date from the Ajalpan and Santa Maria phases. There is even a small, questionable bit of cotton yarn from an Abejas level of Coxcatlan Cave (Zone IX). In addition, boll fragments were found scattered through the deposits, and from these it was possible to determine that only *G. hirsutum* is present. The earliest cotton specimens found were two segments of bolls from Zone XVI of Coxcatlan Cave (El Riego phase). These are the earliest cotton remains yet recovered, but the possibility that they may be intrusive should be noted. A gap of about two thousand years separates these and the next boll fragments, recovered from Zone D of San Marcos Cave (Abejas phase). Cotton was present in all subsequent phases. The fragments range in size from small segments resembling the "wild" type of *G. hirsutum* bolls to those which are indistinguishable from modern cultivated varieties.

Although it is difficult to assess color in old, long-buried samples, the natural color of the fiber recovered seems to range from white to brown. In some samples, the fiber is obviously heavily colored from the surrounding matrix. Artifacts of cotton fiber are described in Volume II, Chaps. 12 and 13.

Bombacaceae (Kapok Family)

Ceiba parvifolia Rose. (pochote). Pochote trees are a characteristic feature of the vegetation in the Tehuacan Valley. These trees are much smaller than the giant ceibas or kapok trees of the lowland tropics. They have served as a source of food from early times, and present-day residents of the valley seem to relish the small dark seeds, which are gathered from wild trees and are eaten raw or boiled. Both the pods from the tree and the bulbous storage roots ("jícama de pochote") appear in the deposits. The floss which surrounds the seeds also appears to have been used. In

at least one case, it was employed to enclose a mass of material which may once have been a dough of ground seeds. Much of the floss found in the deposits may have been discarded from the gathering of seeds.

The earliest fragments of pods were found in Zones XVI and XIV of Coxcatlan Cave (El Riego phase). In subsequent phases in this cave pod remains are numerous. Pods and root fragments were also found in Purron, San Marcos, and El Riego caves.

Cactaceae (Cactus Family)

Cephalocereus hoppenstedtii (Weber) Schum. (tetecho). This tall, columnar cactus grows more abundantly along the west side of the valley than along the east side, but remains of the fruit were found in excavations on both sides. The fruit appears with some consistency in late El Riego and Coxcatlan levels of Coxcatlan Cave, and again in Zone VII, the Santa Maria component. It is absent thereafter. It was also found in a few of the later zones of Purron, El Riego, and San Marcos caves.

Echinocactus grandis Rose (barrell cactus; biznaga). A few woolly mats from the growing tip of the barrel cactus were found in two El Riego phase levels of Coxcatlan Cave and in two Palo Blanco zones of Purron Cave. This material may have been gathered for use as packing or padding.

Escontria chiotilla (Weber) Rose (jiotilla). Jiotilla fruits are currently gathered in season and appear in the local markets in some abundance, but they apparently never played a significant part in the diet of the people in early times. The remains of six fruit were recognized in Tc 50, Zone V (Palo Blanco), and one fruit was found in Tc 50, Zone XI (Coxcatlan).

Lemaireocereus hollianus (Weber) B. & R. A single large spine was found in Tc 50, Zone XVI (El Riego). A stem fragment was recovered in Zone II.

Lemaireocereus stellatus (Pfeiff.) B. & R. (xoconochtle). Fruit remains are represented by four fragments in Tc 50, Zone VI (Palo Blanco) and four pieces in Tc 50, Zone IX (Abejas). Although this tree cactus is now cultivated on the western side of the Tehuacan Valley, it apparently was not very significant in the diet of the ancient people of the valley.

Lemaireocereus weberi (Coult.) B. & R. (cardon). The fruit is gathered and used today in quantity when it is in season. As with the other arboreal cactus fruits, it did not appear extensively in the cave deposits, being present in five zones of Coxcatlan Cave and one zone of El Riego Cave. The earliest remains date back to the El Riego phase.

Fig. 159. Cardon *(Lemaireocereus weberi)* does not fruit regularly, but in fruiting years it bears heavily.

Mammillaria sp. (biznaga). A few whole plants of the small biznaga came from upper levels of the excavations. They do not appear to have been modified in any manner, and it is impossible to judge for what purpose they may have been collected. They were found in Palo Blanco and Venta Salada zones of Coxcatlan and Purron caves.

Myrtillocactus geometrizans (Mart.) Cons. (garambullo). The fruit is currently used wherever this cactus grows. In the excavations, this species is represented by several fragments of stem tissue that span a period from El Riego to Venta Salada times. All were recovered from Coxcatlan and Purron caves.

Opuntia sp. (prickly pear; nopal, tuna). The stems and fruit of the prickly pears have long been important dietary items for the occupants of the Tehuacan Valley. Today, every dooryard has a few prickly pear plants for family use. The people of some villages, such as Azumbilla to the north of Tehuacan, grow extensive fields for nopal (the flat-jointed stems) and tuna (the fruit) to supply local markets. In addition, fruits of many of the wild species are regularly gathered. The plants are started by planting a joint or two in rows without irrigation or subsequent cultivation. The plants soon form a thicket which excludes weedy shrubs. In time, an abundant crop of tunas is borne on the upper pads. The varieties now grown are known as "tuna blanca," which remains a pale green when mature, and "tuna amarilla," which turns a pale yellow. The cultivated fruits are substantially larger than fruits gathered from wild plants. Some of the latter are red when mature. In general, it is impossible to distinguish between the vegetative parts of the wild and cultivated stem joints

Fig. 160. *Opuntia filifera* in flower and with immature fruits. The young pods are eaten as a vegetable.

Fig. 161. Fruit and leaves of cosahuico *(Sideroxylon* cf. *tempisque).*

of the species with edible fruits. Similarly, unless whole fruits are available, it is impossible to distinguish between wild and cultivated fruit fragments or seeds from these fragments. Cultivated plants are probably represented among the archaeological remains, but I have found no way to recognize or separate them. I suspect that *Opuntia* may have been one of the earliest cultivars of the Tehuacan Valley farmers because of the ease with which the plants are vegetatively propagated.

The earliest *Opuntia* remains were mere traces of seed in levels of the Ajuereado phase. Fruit and stem fragments and seed appear regularly thereafter, sometimes in large quantities. Besides almost all levels of Coxcatlan Cave, *Opuntia* remains were present in Purron, El Riego, and San Marcos caves.

Myrtaceae (Myrtle Family)

Psidium guajava L. (guava; guayaba). Guava is now commonly cultivated in the Tehuacan Valley as a dooryard tree. It apparently was a late introduction into the region, since the only fragments of fruit found are four pieces from Purron Cave, Zone E (Palo Blanco). These appear to be from fruit identical with modern seedling-tree fruit. At the period this species appears in the excavations, the Tehuacan Valley was under intensive cultivation with irrigated fields and fruit trees. Guava was undoubtedly brought into cultivation elsewhere before being introduced into the Tehuacan Valley.

Sapotaceae (Sapote Family)

Bumelia laetivirens Hemsl. (tempixquistle). Fruits from several genera of Sapotaceae are now grown in the Tehuacan Valley. Such was not the case in earlier periods. Tempixquistle is one of the two sapotaceous fruits whose remains have been found in the excavations. Seeds appear sporadically in upper levels only—three in Zone VII of Tc 50, one in Zone A of Tc 272, six in Zone B of Tc 254, and one in Zone III of Tc 50. The late appearance of this fruit in the deposits indicates that it was probably introduced as a cultivar. There is no marked difference in the sizes of the seeds found, indicating that there was no active selection for fruit of better quality. If this fruit had been gathered from wild trees, remains should have appeared in earlier levels.

Sideroxylon cf. *tempisque* Pitt. (cosahuico). Cosahuico has long been one of the more popular fruits of the Tehuacan region. The tree was apparently native along watercourses in the barrancas, since seeds of cosahuico appear early, in levels of the El Riego phase, and continue in increasing numbers throughout the sequence. Cosahuico trees were observed in full leaf in some rather dry sites in the winter of 1966, so the species must be able to persist under fairly inhospitable conditions.

Some of the recovered whole seeds were measured and an index figure derived by multiplying the length (in cm.) by the width (in cm.). Seeds recovered from Coxcatlan Cave, Zones XVIII (El Riego phase) and XII (Coxcatlan phase), averaged respectively 3.12 and 3.20. These seeds probably were collected from wild trees. In the large sample from Zone XI (late Coxcatlan phase) of the cave, the average $l \times w$ increased to 3.46,

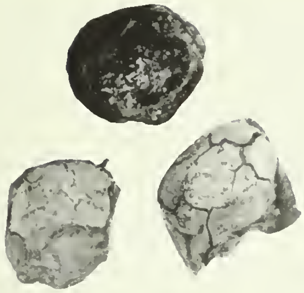

Fig. 162. Dried fruits *(left)* and seed of cosahuico, Tc 50, Zone IX, actual size.

Fig. 163. Black sapote *(Diospyros digyna)*: fruit, calyx, skin, and separate seeds.

an indication that fruit of large size may have been selected for propagation. The increase in size continues but becomes more gradual in late horizons. The largest average, 3.88, is for a lot of seeds from Zone D of Purron Cave (Palo Blanco phase). It seems obvious that irrigated orchards of superior fruit were being grown near this site.

Fruits like cosahuico are not of primary importance in the diet of the valley people, but are seasonal items which provide palatable differences in texture and flavor from primary diet foods. The appearance of such foods in abundance may indicate either that the food economy has developed sufficiently to permit time to be spent gathering secondary food items or that the plant has been brought into cultivation to provide a plentiful supply of fruit. The presence of 271 cosahuico seeds, together with remains of black and white sapotes and coyol, in Zone XI of Coxcatlan Cave, seems to be such an indication and suggests that at least a primitive form of irrigation may have been practiced as early as the Coxcatlan phase.

Ebenaceae (Ebony Family)

Diospyros digyna Jacq. (black sapote; zapote negro). Black sapote is found today in almost every dooryard in the valley where fruit trees are grown. It has long been a popular fruit. Black sapote does not occur today as a native member of the flora of the valley, and it cannot survive in the area without irrigation during the dry part of the year. In spite of the fact that the ground water level must once have been higher during the wet seasons, the remains of the native flora in the excavations show that the climatic regimen has apparently remained unchanged from about 7000 B.C. to the present day. Thus, at no time in the past would there have been sufficient water available during the dry season to enable black sapote to persist in the valley without irrigation. Its appearance in the Coxcatlan phase (Tc 50, Zone XI), along with other fruits from trees requiring supplementary water during the dry season, must indicate that the local people knew this and were prepared to provide water for these trees.

Black sapote seeds were found in all but one level of Coxcatlan Cave from Zone XI onward. Quantities were not very large except for two instances—50 seeds in Zone IX (Abejas phase) and 291 seeds in Zone VI (Palo Blanco phase). Small numbers of black sapote remains were recovered from one level of Purron Cave and the upper four levels of the East Niche of El Riego Cave. Because each fruit contains a number of seeds in a thick flesh, the amount of seeds recovered does not reflect the exact quantity of fruit used.

Apocynaceae (Dogbane Family)

Plumeria rubra L. var. *acutifolia* (Poir.) Woods. (red jasmine). A portion of inflorescence of this lanky native shrub was recovered from Tc 50, Zone IV (Palo Blanco). Called "flor de mayo" in some parts of Mexico, the flowers are used as religious decorations. No such tradition could be found for this plant near Tehuacan, and I suspect the single fragment was an accidental intrusion.

Thevetia peruviana (Pers.) Merr. (venenillo). Venenillo is known as a poisonous plant in the Tehuacan region today. Five seeds of this tree, one from Tc 35e, Zone C (Venta Salada), and four from Tc 254, Zone B (Palo Blanco), may have been gathered as medicinal plant material—or they may have been brought into the caves for more sinister reasons. The species has no significance as a food plant, nor is any other useful product known to be derived from it.

Solanaceae (Nightshade Family)

Capsicum annuum L. (chili pepper). Fragments of chili peppers are not particularly numerous, but they

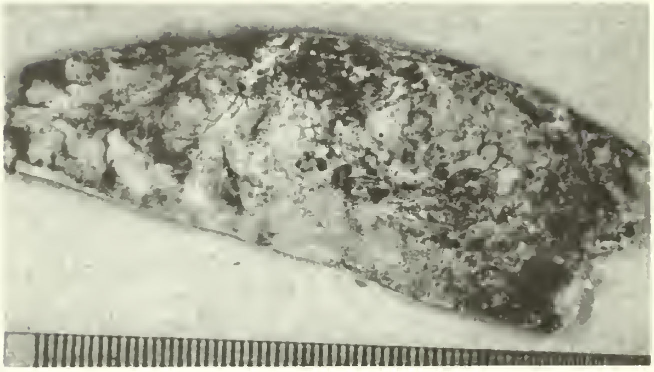

Fig. 164. Pod of chili pepper *(Capsicum annuum)* from Tc 50, Zone II, is indistinguishable from dried chilis sold in local markets today.

Fig. 165. Cache of tomate or ground cherry *(Physalis* sp.) from Tc 254, actual size.

were found as far back as Zones XIX, XVI, and XV of Coxcatlan Cave (El Riego phase) and in coprolites from Zone XIV. Chili is another of the plants which are native to a more mesic habitat than is available in the valley now or has been available during the period covered by the plant remains. Early fragments may have come from fruit gathered in the more mesic areas along the barrancas higher in the mountains, in areas where avocados could also be gathered. All of the wild or feral plants of chili which I have seen bear small fruit. The large fragment found in Tc 50, Zone XI (Coxcatlan phase), cannot be distinguished from modern cultivated varieties. The plant was almost certainly in cultivation in Coxcatlan time along with squash, gourd, and the common bean, which are also represented in the remains of that phase. Chili remains came from Coxcatlan Cave and the late levels of El Riego Cave. They were not recovered from other excavations.

Physalis sp. (ground cherry; tomate). Two small caches of fruit were recovered from Palo Blanco components of San Marcos Cave, 25 fruits from Zone B and 28 fruits from Zone C[1]. The fruits are small, little resembling the large-fruited varieties found in the Tehuacan market today. They could have been gathered from wild plants or they could have been under cultivation, but they were obviously not highly selected for size.

Bigononiaceae (Bignonia Family)

Crescentia cujete (tree gourd; calabaza). Fragments of tree gourds are described in Chapter 11 in conjunction with remains of *Cucurbita*. In addition, a single winged seed of an unidentified member of the Bignoniaceae was found in Tc 50, Zone III.

Cucurbitaceae (Squash Family)

Cucurbita mixta Pang., *C. moschata* Duchesne, *C. pepo* L. (squash, pumpkin; calabaza). Remains of these species and of *Lagenaria siceraria* (Mol.) Stadl. (bottle gourd), are discussed in Chapter 11 above.

Compositae (Sunflower Family)

Several dried heads of unidentified species of this family were recovered. None of them were the sunflower which was cultivated by Indians in the southwestern United States. They were probably brought into the caves as medicinal plants. The following fragments were recovered: Tc 35e–C, 3 (Venta Salada); Tc 35e–D, 1; Tc 254–B, 3; Tc 254–C[1], 1; Tc 50–V, 2 (Palo Blanco); Tc 50 VII, 1 (Santa Maria).

The Vegetal Remains, Meteorology and Geology

The plant remains from the Tehuacan Project comprise one of the most complete histories of the agricultural pursuits of a group of people which has yet been discovered. Furthermore, they summarize the local vegetation and its history as no other method can. From the evidence furnished by the plant remains, inferences concerning the climate of the area over the last 9000 years can be drawn.

The usual means of estimating the stability of or changes in the climate of an area depend upon records left in geological formations by the movement of water. Less frequently, biological evidence in the form of fossil pollen or the remains of animal skeletons may

provide some index to past climate. Rarely has the continuous record of local vegetation been available to furnish direct evidence of the climate of an area.

From the many reports on the post-Pleistocene of the north temperate regions of the world, a picture of climatic fluctuations may be drawn. Alternating periods of more or less rainfall have left their records in varved clays, old shorelines, terraces, and changing pollen to such a marked degree that Pleistocene geologists have drawn general conclusions stating that post-Pleistocene climate has fluctuated markedly in North America. With such background, the flora of the Tehuacan area shows no agreement.

The earliest plant materials from the deposits in Coxcatlan Cave can be dated roughly 9000 years before the present. From the few remains at this level and the increasing numbers of native plant species found in the later levels of the deposit, it is evident that no change in the species composition of the local flora has occurred. Since the flora of the area is largely controlled by the lack of available rainfall, even the smallest increase in mean annual precipitation would result in the elimination of some species at the expense of others. In more mesic environments, minor fluctuations in rainfall would not have so marked an effect, and a small climatic change might go unnoticed in the species composition. The long-sustained uniformity in climate has resulted in the development of a surprising amount of endemism in the local flora. Climatic uniformity is probably one factor permitting the early development of agriculture among the people of the valley, since they would have long known the limitations of the local rainfall pattern.

Dramatic changes in the valley's flora would have occurred had the rainfall pattern of the valley altered from its present regimen. While it is true that the current rainfall is not great when the mean annual temperature and the rate of evaporation for the area are considered, the same amount of precipitation spread more evenly through the year would be much more effective. In such conditions, a nearly complete vegetational cover would probably prevail and most of the rainfall would then be used by the plants. Under present conditions, which the native plant remains certify as having prevailed from the beginning of the botanical record, much of the precipitation falls within a relatively short period of the year. During the prolonged dry season, all of the annual herbaceous plants dry up, and most of the shrubs and trees lose their foliage. Much of the precipitation fails to penetrate the soil but rushes off the slopes and down the watercourses of the valley where it is completely unavailable to the plants.

Patterns in agricultural development

From the abundant plant remains, the development of agriculture in the Tehuacan Valley may clearly be seen. One of the most striking examples is the modification of maize (*Zea mays*) under cultivation. It is evident that maize was first gathered in the valley as a wild plant. (see above Chapter 9). All evidence suggests that it was an annual plant of the canyons and barrancas whose seed survived the dry period in dormancy in the sun-baked soil. With the coming of the rains in May and June, the seed germinated, and the plant grew and matured with the culmination of the rainy season in September. Once the maize plant was brought into cultivation during the Coxcatlan phase, selection forced rapid modifications in the structure of the grain-bearing spike.

The maize remains tell something of the impact of cultivation of a staple food on the diet of a people. For several thousand years (from about 5000 to 1500 B.C.) while the development of modern maize was taking place, the new crop obviously took only a limited place in the diet of the people. Once the high productivity of maize in an essentially modern form was well established, the use of maize quickly expanded until it became the staple diet food.

Setaria macrostachya was another widely used starch source among the people of the Tehuacan region. This grain was first gathered along with other grass seed and then possibly was cultivated in abundance. From the large, compact heads, thousands of small fruits (caryopses) would be winnowed for grinding and conversion into gruel or tortillas. Long before maize appeared among the plant remains, setaria was a primary starch source. After maize came into cultivation, setaria continued to be an important starch source. Since there is no apparent modification of setaria through selection for larger fruit, no character of the recovered remains provides a clue to the date at which it may have been brought into cultivation. The first remains of this species were found in late Ajuereado and early El Riego levels of before or about 6500 B.C. At this stage, it was probably gathered from wild stands of grass in the barrancas and canyons or along the watercourses in the valley. I believe that it was probably brought into cultivation considerably earlier than maize, perhaps as early as the middle of the El Riego phase. The abundance of setaria and other grass remains in Zones XVI–XI of Coxcatlan Cave indicates that it was available in such quantities that the people could be somewhat wasteful in its use.

Other plants in the traditional modern Mexican diet of maize, beans, chili, and squash appear in the Tehua-

can deposits. Beans and squash are discussed separately in Chapters 10 and 11, but a few general observations may be of interest here. Three species of *Cucurbita* were known to the Tehuacan people as well as the bottle gourd, *Lagenaria siceraria*, and the tree gourd, *Crescentia cujete*. *Cucurbita mixta* and *C. moschata* are the first cultivated species definitely to be identified in the deposits. Two seeds which are apparently *C. mixta* came from a late El Riego level of Coxcatlan Cave and both *C. mixta* and *C. moschata* appear in components of the Coxcatlan phase, as do remains of the bottle gourd. *C. pepo* as a cultivar apparently entered the area later, perhaps in the Ajalpan period and definitely by Palo Blanco times.

Bean remains appear under contexts which indicate that all species were known only as cultivated plants. *Phaseolus vulgaris* fragments, the oldest bean specimens, appear first in the Coxcatlan phase and reoccur throughout the sequence. Tepary beans (*P. acutifolius*) appear in an Abejas level and again in the Palo Blanco period. Remains of the *Canavalia* bean appear briefly during the Abejas phase. Runner beans (*P. coccineus*) appear in Santa Maria and Venta Salada levels. Remains of the small lima bean (*P. lunatus*), were uncovered in Venta Salada levels.

The chili pepper has long been an established dietary item in the Tehuacan area. Fragments of *Capsicum* sp. appeared in the refuse as early as the El Riego phase. Although the earliest chili remains might have been gathered from wild plants growing along the watercourses, *Capsicum annuum* is not a native plant in the thorn-scrub forest of the valley. None of the characters of the earliest fragments indicate cultivation, but I believe that chili was among the earlier cultigens in the area, since it would have grown near the occupation sites only with human care. It probably was brought into cultivation in the middle or latter part of the El Riego phase.

In addition to the maize, beans, chili, and squash normally associated with indigenous food preferences, maguey and *Opuntia* fruits and stems must be considered. These items are important supplementary foods today; evidence from the Tehuacan cave deposits indicates that they may once have been major items, at least during a portion of the year. One *Opuntia* fruit fragment and traces of seeds appear first in the Ajuereado phase. Nopal or stem fragments appear in the following phase. Fragments of maguey first appear early in the El Riego phase. Both maguey and tuna are sources of sugar, and the nopal pads are a green vegetable. These foods are available during the dry season, when many other foods are not.

Maguey plants furnish many raw materials for the local people: the flowers of some species and bases of young leaves of others are foodstuffs which may be used raw or cooked; the leaves, split and dried, make small, very tough boards; the sap is a refreshing beverage as *agua miel* or a mild intoxicant as pulque; the inflorescence stalk is a long, straight pole in a region otherwise destitute of poles; finally, the fibers of the leaves may be stripped out in coarse bunches for rough tying or completely retted and cleaned from young leaves to furnish fine fiber which may be twisted into thread, woven into fabric, or worked into sandals. From the archaeological evidence, it cannot be proved that maguey was put to all of these uses from its earliest appearance in the deposits. However, chewed leaf material in the form of quids appears as early as Zone XVIII of Coxcatlan Cave, proving the use of maguey as food. The use of maguey sap was almost certainly known quite early, and since it does not take *agua miel* long to become pulque in the Tehuacan climate, it can be assumed that pulque did not remain long undiscovered.

Maguey and *Opuntia* are both gathered and cultivated at the present time in the Tehuacan area. Every dooryard has a few plants. Frequently, they are planted as borders to fence cultivated fields and terraces. Both are propagated vegetatively, maguey from offshoots and *Opuntia* from stem joints. The botanical characteristics of the strain of plants is thus transmitted unchanged from generation to generation, so long as a plant does not die completely. Both plants also may be raised from seeds, but this form of reproduction is not used intentionally by Mexicans today. Selection of superior varieties from a variable cultivated seedling population has never been extensively practiced. Fruits of cultivated *Opuntia* varieties do differ in size and sometimes in color from fruit of wild forms. Otherwise the yardstick by which domestication is indicated so clearly in some crops is lacking in *Opuntia* and maguey.

On the other hand, the ease with which both plants may be vegetatively propagated leads to the suspicion that the idea of cultivation resulted from someone's observing that a carelessly discarded *Opuntia* stem joint rooted and grew. From such an observation it is a small step to the transplanting of maguey offshoots to a place where they would be more accessible. Furthermore, both plants are succulent natives of dry hillsides and porous canyon walls, where they receive a minimum of moisture. They would survive under conditions that would destroy more tender plants. In spite of lack of evidence to prove it, I am convinced that nopal and maguey are the earliest cultivated plants of the

Tehuacan region. They could have been, and probably were, in cultivation by the middle of the El Riego phase.

Mesquite is another plant which today is both a wild food source and grown as a cultigen. Remains of this plant from the Ajuereado phase place it among the earliest food plants of the Tehuacan people. Along with setaria, mesquite was proportionally more important in the Tehuacan diet before about 4500 B.C. Despite the sudden increase in the importance of maize, mesquite—unlike setaria—maintained its popularity and its place in the diet. Although a date for the cultivation of mesquite cannot be determined from the remains in the deposits, I believe that mesquite trees probably were first cultivated in the El Riego phase, when other native plants of the Tehuacan region may have been brought into cultivation.

Accompanying mesquite in the deposits of the Ajuereado phase is a seed of chupandilla, *Cyrtocarpa procera*, a fruit tree native to the thorn-scrub forest in the Tehuacan Valley. From El Riego times chupandilla is persistently present among the plant remains and formed an important portion of the diet throughout the sequence covered by the deposits. The striking increase in the amount of chupandilla remains in Coxcatlan times implys that the tree may have been brought into cultivation to form a major constituent of the pre-maize food complex. Even after maize became the staple food plant of the valley, chupandilla maintained a prominent place in the diet, as the data for Coxcatlan and Purron caves show. The marked fluctuation of and increase in the size of chupandilla seeds from Coxcatlan times to the most recent levels shows that selection for fruit of better quality was actively practiced by the farmers of the area.

The immature pod of the leguminous tree, *Leucaena esculenta*, a rather minor food plant, was gathered from native trees in El Riego times and is still gathered today, although the larger part of the modern crop comes from cultivated trees planted in dooryards. The pods are called "guaje." From the same trees, during the last few months of the dry season (March, April) people gather "polochocos," which are galls or abnormal growths of plant tissue caused by flies of the group *Cecidomyiidae*,* which lay eggs in the plant tissue. Today the galls are prepared by boiling. No archaeological remains identifiable as polochocos were found and the custom of preparing and eating them cannot be accurately dated. Since the practice is a local one known only to the Indian inhabitants of the Tehuacan area, it might be a tradition with its roots far in the past. Guaje fragments appear only once in the El Riego horizon, and it is by inference that cultivation is assumed for the tree by the close of that phase. Other early remains are sporadic and very few. In the Santa Maria phase the amount of guaje increased, and the tree was certainly in cultivation from this period to the present.

The use of fruit crops by the people of the Tehuacan area is well documented by the remains of fruit found in the deposits. Avocado is one of the two earliest fruits used. (The other, as we have noted, is chupandilla.) The avocado pit recovered from Coxcatlan Cave, Zone XXIV (Ajuereado phase, about 7000 B.C.) is the earliest record known for this fruit. It probably was gathered from a native tree standing along a watercourse, perhaps in a nearby barranca. The avocado, as I have pointed out, is not found in the thorn-scrub-cactus association across the floor of the valley and will not grow away from a permanent water supply. The high oil content of the fruit must have made it particularly desirable, and it is probable that in the El Riego phase trees were transplanted to watercourses near dwelling sites. From this period to the present time, the avocado remains a popular dietary item. Note that most of the avocado seeds were found in levels of Coxcatlan and Purron caves.

Another fruit whose remains were recovered in early levels is *Spondias mombin*, or ciruela. Ciruela, once it is established, will tolerate somewhat drier soil and more adverse conditions than avocado. The earliest lot of ciruela seeds, 200 in number, suggests the gathering of crop fruit. Ciruela is found in relative abundance throughout the deposits. Again the largest amounts were recovered from Coxcatlan and Purron caves.

The only other fruit with an ancient distribution pattern that undoubtedly included the watercourse margins of the barrancas is cosahuico (*Sideroxylon* cf. *tempisque*). Cosahuico first appears in levels of the El Riego phase. The remains of this fruit indicate that it probably was gathered until middle Coxcatlan times, when a sudden increase in the number of cosahuico seeds suggests that trees were planted near the sites. The fruit of cosahuico remained popular throughout the sequence. During the Coxcatlan phase, cosahuico seeds increase in size significantly, suggesting that the selection of seed for planting may have been underway for a long time. Proportionally, the greatest amount of

* Identified by G. Steyskal, U.S.D.A. *Cecidomyiidae* are, in turn, often parasitized by a wasp of the group *Torymidae*, *Torymus* sp. (identified by B. D. Burks, U.S.D.A.). Both insects are present in the polochocos when they are eaten.

cosahuico material came from Coxcatlan and Purron caves.

A significant change in the quantity and kind of fruit remains found in the deposits occurred in the middle of the Coxcatlan phase. At this point, the amount of material recovered becomes significantly larger. Also, three species are added to the list of fruit remains; coyol (*Acrocomia mexicana*), white sapote (*Casimiroa edulis*), and black sapote (*Diospyros digyna*). None of these species are native to the valley flora, nor are they known to be present along the watercourses. None become truly abundant in the recovered plant remains (both black and white sapotes have several seeds per fruit so that a number of seeds may represent fewer fruit than do seeds of avocado, ciruela, cosahuico, and coyol). None of these species can grow in the Tehuacan Valley without a supplementary water supply. The conclusion, then, is that all three species—coyol, white sapote, and black sapote—were brought into the area in cultivation and under such circumstances that they were not needed as a primary food source. The fruits of these plants apparently were a pleasant supplement, a luxury enjoyed by the people because the development of agriculture had progressed sufficiently to permit easier accumulation of basic food materials. Furthermore, I interpret the presence of these fruits as evidence of the controlled use of the valley's water resources, permitting year-round watering of plants which would not otherwise grow in the Tehuacan region.

Several other plants make brief or late appearances in the archaeological remains. One of these, a minor fruit called tempixquistle (*Bumelia laetevirens*), appears first in the Santa Maria horizon and then sporadically to the top of the deposit. It is still grown in the valley as an occasional tree, but it cannot be said to be important or popular. The currently ubiquitous guava appears only once, in a Palo Blanco level of Purron Cave, and cannot be classed as an important addition. Fruit of a native *Physalis* sp. was found in San Marcos Cave in two Palo Blanco levels, but was not found elsewhere. Since the cultivated "tomate," *Physalis*, is a prominent plant in the Tehuacan area today, the brief appearance of a related plant raises the question of the early introduction of tomate into the region. I believe that the San Marcos material was probably a chance cultivation of a local plant which was sometimes gathered, but it was not found desirable enough to continue its cultivation. It probably has nothing to do with the currently cultivated species of *Physalis*, which I feel was brought into the area after the Spanish conquest.

Finally, peanuts (*Arachis hypogaea*) appeared in Coxcatlan Cave in a Palo Blanco component tentatively dated about 100 B.C. A few later remains were present, but never in abundance. The peanut was evidently a useful secondary addition to the Tehuacan diet because it persisted. The avocado, however, seems to have remained the primary source of vegetable fat for the people of the region.

The late appearance of three of the plants we have been discussing provides an interesting point for speculation. Peanuts, guava, and a species of *Bumelia* are known from archaeological excavations in coastal Peru at a much earlier date than they were found in Tehuacan. It is not certain, but every possibility exists that the three species were introduced into Mexico from Peru shortly prior to the time at which they appear in the Tehuacan deposits. I expect to see these plants appear in other dry deposits in southern Mexico under contexts datable within 200 to 300 years earlier than they appear in the Tehuacan Valley and represented by sufficiently distinct varieties that they can be firmly connected with Peruvian archaeological varieties.

The final cultivated plant to be considered is cotton (*Gossypium hirsutum*). The earliest cotton finds yet known are the segments of cotton boll from Coxcatlan Cave, Zone XVI, an El Riego component which can tentatively be dated between 5500 and 6000 B.C. It cannot be proved that the fragments were picked from a cultivated cotton plant, but neither can it be disproved, because other plant remains can be interpreted to show that some species apparently were in cultivation in the Tehuacan area at this time. There is, however, a possibility that the boll fragments are intrusive, since cotton plant fragments are absent from the Coxcatlan horizon. They next appear in Abejas and Ajalpan phase levels of San Marcos Cave and are present in all subsequent horizons. Artifacts made of the fiber appear from the Ajalpan phase throughout the remainder of the sequence.

Significance of the Tehuacan Vegetational Remains

It is obvious from the evidence presented by the vegetational remains found in the Tehuacan excavations that archaeological plant remains present a true record of the vegetational history of the local area. This bears out the pattern found in the previously discovered dry sites in which plant remains have been preserved. In New Mexico, the Bat Cave deposits (Smith 1950) showed that the inhabitants used only the local plant resources which reflected the local climatic variations during the time of occupation of that site. Simi-

larly, the vegetational remains from the Huaca Prieta in Peru (Bird 1948) reflect the local vegetation. Another example is provided by the long sequence reported for Danger Cave, Utah (Jennings 1957). The Tamaulipas caves (MacNeish 1958) also disclosed a long sequence in which vegetational remains correlated closely with the local ecology. In every instance so far reported for the American area, no abrupt change from local to foreign plant species has occurred.

Man today is notably resistant to changes in habits and particularly to changes in food preferences. In the United States, vast budgets are expended to present new products to a sophisticated public well calloused by the impact of change, yet the acceptance of any radically different food product is slow. Far in the past, when existence depended on a satisfactory equilibrium established by man with his immediate environment, acceptance of introduced and unusual foods would have been even slower. Beyond the fact that no leisure time was available for people to explore widely for new foods, human inertia forbade the undertaking. Some men may have been, and still are gamblers, but few will exchange a sure, but poor, existence for a grand, but improbable, surfeit. Even were he willing to take the chance, a man's dependents frequently would not let him try.

Once cultivation of plants has become established as a surer means of producing food, people are released from the tense struggle for basic subsistence. The excavations made to date covering in detail the change from a gathering economy to an agricultural economy have not been many. The excavations of the Tamaulipas caves covered two such sequences (MacNeish 1958). However, there were major gaps in the temporal sequence in the excavations in the Sierra de Tamaulipas area which can only be filled by extrapolation from the vegetal remains in the intervening levels. The first cultigen used by these people was the squash, *Cucurbita pepo*. The increased food value of cultivated strains of this plant could do little to alleviate the immediate needs, and it was not until maize became an established crop that the Tamaulipas people were able to forego some of their gathering activities. Perhaps because of poorer soil and water resources, the Sierra de Tamaulipas farmers never developed a highly successful system of farming into which there were repeated introductions of new, largely luxury food items.

The Ocampo caves of Tamaulipas (Whitaker, Cutler, and MacNeish 1957; Kaplan and MacNeish 1960) provide longer continuous sequences from which it can be judged that the extrapolations used in the Sierra de Tamaulipas interpretations could not be far from correct. While these excavations show that the development of agriculture among the people of the Sierra Madre progressed to a more refined state than it had farther north and east, the cultigens were still limited. Besides the early appearance of *Cucurbita pepo* (which seems to have been domesticated here), later horizons showed that these people cultivated *C. moschata*, *C. mixta*, three kinds of beans (*Phaseolus coccineus*, *P. vulgaris*, and *P. lunatus*), maize, and chili peppers. In addition, cotton became a crop plant whose fibers were utilized for the production of fabrics and so on. It is evident from the cultural remains that these people attained a higher cultural level than their neighbors in the Sierra de Tamaulipas, but they also accepted no luxury food items into their agriculture.

No other excavation covering the change from a gathering economy to an agricultural economy has come to my attention. The two Peruvian excavations in which abundant plant remains have been recorded at early levels, Viru Valley (Strong and Evans 1952) and Huaca Prieta (Bird 1948; Whitaker and Bird 1949), expose sequences in which the lowermost cultural level already represents an agricultural-fishing people. The lowest levels of the Huaca Prieta dig contained gourd, squash (*Cucurbita moschata*), and cotton remains from cultivated plants. Huaca Prieta may represent an earlier period than the Viru Valley levels, although this is very difficult to determine from the respective reports. At any rate, the transition to agriculture was not found; the progress of agriculture in later levels of both sites seems to have been slow. Beans (*Phaseolus vulgaris*), maize, avocado, peanuts, chili, and calabaza were introduced into the local agriculture, but over-all agricultural advancement apparently was limited. Guava remains were found in both of these sequences, and it is probable that this plant was in cultivation in coastal Peru. Considering the small complex of local plants which made up the diet in the lowest levels, the people of Huaca Prieta and the Viru Valley became quite adventurous in accepting such luxury items as avocado and guava into their diet. Whenever it appears, maize cannot be considered a luxury as it rapidly assumes the role of prime food source. Both beans and peanuts are secondary foods in most primitive diets, but they cannot be considered truly luxury since they fill an important dietary position through their individual food values. From the standpoint of flavor, under the primitive conditions under which they were undoubtedly prepared, neither could be considered a luxury.

The sequence of development shown in the Tehuacan excavations is unparalleled. From the earliest levels of the excavations, the people obviously practiced a

gathering economy utilizing a limited number of local plants. The number of plant species involved may be deceiving, for it is likely that other plant parts were utilized in season at locations other than the site of the excavation. Even from the vicinity of the excavation site, tuna or other fruit might not have found its way into the cave in sufficient quantity to have been recovered in the excavation.

Once agriculture became established in the Tehuacan region, the development of crops and the introduction of new items into cultivation seems to have proceeded at a rapid pace. I believe the earliest Tehuacan cultigens were probably maguey and *Opuntia*, owing to the ease with which these species are vegetatively propagated and because they are regular dietary items in the area. How long thereafter or under what conditions the people discovered that the grain, setaria, could be cultivated is not shown by the evidence in hand, but probably this species, avocado, and chili peppers must soon have been added to the list of cultigens. Thereafter, innovations in local diet and additions to the list of cultigens proceeded at an unprecedented rate. *Cucurbita mixta*, gourds, ciruela, and perhaps cotton soon were grown in the valley.

The evidence in support of the tremendously important innovation entailed in the controlled use of the water supply in Coxcatlan times is secondarily important in that the introduction of luxury foods occurred at this time. The squash, *Cucurbita moschata*, which appears in the deposit at this time, can be considered a secondary food with enough value to remove it from the luxury category. The same cannot be said for black and white sapotes and coyol, which are fruits with widely different flavors and little standing as necessary dietary items. There can be no doubt that the Tehuacan people very early arrived at a high stage of sophistication in their dietary preferences. Through a rapid development of agricultural techniques, coupled with the partial release from climatic variables provided by irrigation, the early bondage to full-time search for a bare subsistence was broken.

All of the later additions to the list of Tehuacan cultigens were luxury items, with the possible exception of small lima, or sieva, beans (*Phaseolus lunatus*). The three cultigens, peanuts, guava, and tempixquistle, are items which supplement previous cultigens providing essentially the same food values or flavors. The fruits, particularly, were superfluous, as there were already several kinds of fruits in cultivation.

Although it probably was not one of the earliest cultigens, maize undoubtedly was brought into domestication in the valley during Coxcatlan and Abejas times, (see Chapter 9). Once the value of maize as a diet staple and as an efficient yield producer was established, it rapidly became disseminated. An earlier cultigen may have been the chili pepper, which was apparently among the first cultivated plants. Chili provided flavor in a diet which originally must have been somewhat monotonous. This plant also soon became widely disseminated or was quickly brought into cultivation from wild plants once the techniques of cultivation became known. I am convinced that *Opuntia* and maguey were introduced into cultivation very early in the valley, although the lack of modification through vegetative reproduction precludes recognition of these as cultivated plants among vegetal remains.

Avocado was first cultivated in the Tehuacan region perhaps as early as 5000 or 6000 B.C., but the influence of selection on fruit size is not apparent until the Santa Maria phase of 900–200 B.C. The much longer time between generations of fruit trees precludes the rapid developmental picture which is shown by maize.

It is possible that ciruela and cosahuico were first brought into cultivation in the Tehuacan Valley, and that mesquite and chupandilla may have been among the very earliest tree crops. As in the case of avocado, ciruela shows little change through a long period after it apparently was brought into domestication. Mesquite remains are essentially the same throughout the deposits. Cosahuico shows an increase in size in early levels, which continues, although more slowly, in later levels. Chupandilla shows a definite increase in size in later horizons, but it has not been found in any archaeological deposit outside of the Tehuacan region, and it was probably not widely distributed.

The introduction of peanuts and guava and the use of tempixquistle about 200 B.C. are exciting and almost certain proof that the people of southern Mexico were in contact with the culture which had developed in coastal Peru (Fig. 73). Peanuts and guava were found in Peruvian excavations at a much earlier date, but under conditions in which it is certain that peanuts were cultivated. Guava could also have been cultivated in Peru during the period in which it is represented.

Contacts between the major areas of high culture in North and South America are evident at a much earlier period, though. With the recovery of *Cucurbita moschata* fragments at a very early level in Tehuacan, I am certain that this species originated in North America and was transported to Peru by 2000 B.C. Maize and common beans appear in the archaeological record in Peru about 1000 B.C., after a long period of use in Mexico. All of these crops represent either a

prime staple (maize) or prominent secondary foods (squash and beans) whose value is certainly immediately apparent to the recipient. This would lead to their appearance in archaeological sites very shortly after they were known. Regular contacts between North and South America can be assumed by at least 1000 B.C. and, perhaps, as early as 2000 B.C.

The study of the archaeological plant remains from the Tehuacan Valley has been an exciting and highly rewarding experience. Many previously unknown and unpredicted facts have been disclosed. More important, the entire history of American plant cultigens has been advanced immeasurably. What had once been empty conjecture concerning the areas of origin or the routes of dissemination of several important plant species has been proved. It is now possible to say with confidence that cultivated plants had many different points of origin and differing routes and rates of distribution.

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CHAPTER 13

A Cotton Boll Segment from Coxcatlan Cave

Stanley G. Stephens

Two cotton boll segments were uncovered in Zone XVI of Coxcatlan Cave, a level representing the El Riego phase and dating to about 5500 B.C. In their report on this material, Smith and MacNeish (1964) thought that the two segments were apparently from the same boll. Their illustrations show that both segments were as long as or longer than those of a modern Upland cotton. One of the segments was uncurled with boiling water, and they concluded that it "represented one-fifth of a boll about 3 cm. in diameter." Presumably this implies that they interpreted the segment as being part of a five-lock boll.

The following observations deal with the second boll segment from Zone XVI, which has not been processed or otherwise manipulated.

Lock Number

A mature but unopened cotton boll is roughly circular in cross section, and its interior is divided by vertical partitions or "septa" into chambers ("locks"). The number of locks varies from three to five. When ripe, the boll splits vertically along the middle of each lock from tip to base, and so becomes divided into three to five segments. If, as is usually the case in archaeological material, the segments become completely separated from each other, it should be possible, theoretically, to determine by measurement whether an isolated segment was derived from a boll of three, four, or five locks. This follows from a consideration of the simple geometry of the boll (Fig. 166). The width of the septum (r) provides an estimate of the radius of the boll; the width of the segment (s) multiplied by the number of locks (n) measures the circumference of the boll. Thus, if one can measure both r and s, one can estimate the number of locks from the relationship $2\pi r = ns$.

The ratio s/r should be 2.10 for a three-lock boll, 1.57 for a four-lock boll, and 1.26 for a five-lock boll. However, during drying and storage the tissues of the boll may undergo considerable shrinkage and curvature, and the question arises whether the foregoing theoretical relationships would be valid for dried boll segments or whether they would be vitiated by differential shrinkage.

Some material available in the Genetics Garden at Raleigh, North Carolina, in 1966 was used to test the relationship. It consisted of an interracial hybrid, RV, belonging to the species, *Gossipium hirsutum*. RV in general is similar to modern Upland Cotton varieties, but is more variable in boll shape and lock number. Bolls varied in shape from nearly round to broadly ellipsoidal in vertical section; the number of locks varied from three to five. Random samples of dried-out bolls were collected from this material, three-,

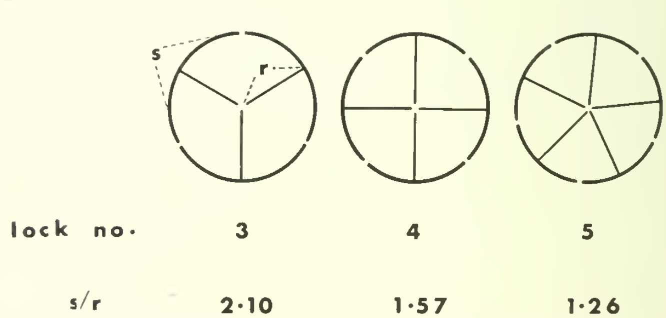

Fig. 166. Geometry of cotton bolls seen in cross section: r, width of septum; s, width of segment.

Table 27. Maximum Width of Septum (r) and Segment (s) and the s/r Ratio of 10 Samples Each of Dried 3-, 4-, and 5-Lock Bolls of RV (hirsutum) (*in mm.*)

	r	s	Calculated s/r	Theoretical s/r
RV 3-lock	8.2 ± 0.35	20.1 ± 0.57	2.45	2.10
RV 4-lock	10.3 ± 0.28	17.8 ± 0.55	1.73	1.57
RV 5-lock	11.4 ± 0.22	15.9 ± 0.35	1.39	1.26
Tehuacan boll	11.8 –	19.0 –	1.62	–

four-, and five-lock bolls being collected separately. From these random samples, ten segments from each lock-number category—each from different bolls—were selected for measurement. The mean values of *r* and *s* measurements of segments sampled from three-, four-, and five-lock bolls are compared in Table 27. Differences between these means are highly significant, showing that even after drying, characteristic differences in the dimensions of three-, four-, and five-lock bolls are preserved. Thus, although the samples are very small, the differences would appear to be real and reliable.

From these measurements the ratios, s/r, can be calculated for comparison with the theoretical values. It can be seen that the calculated ratios are of the right order, but that there is a consistent discrepancy from the theoretical ratios, the calculated values being larger than expected. The discrepancy is readily explained by the fact that the calculated ratio does not take into account the thickness of the boll wall. (Width of septum was deliberately measured from the edge of the septum to the *inside* of the boll wall, because this can be measured quite accurately. It is a more practically useful measurement than a measurement which includes the thickness of the boll wall, since the latter cannot be measured when the wall is strongly reflexed by drying.) If one adds the arbitrary but reasonable correction of one mm. to each of the *r* values to allow for thickness of boll wall, the s/r ratios would have the following values: three-lock, 2.18; four-lock, 1.58; five-lock, 1.28. These agree remarkably well with the theoretical ratios.

At the foot of the table are shown the measurements of the boll segment from Coxcatlan Cave. It was possible to measure *r* accurately; *s* could only be measured crudely, because of the strong reflexion of the boll wall. It was measured by molding a strip of thin aluminum foil to the reflexed surfaces on either side of the septum, marking the limits to be measured with a scalpel, removing the foil, and measuring it flat. The sum of the two measurements plus the thickness of the septum (measured by calipers) gives the estimate of 19 mm. shown in the table. The calculated s/r ratio (1.62) lies between the values expected for four and five locks and closer to the former. This suggests that the Tehuacan boll segment came most probably from a four-lock boll, possibly from a five-lock boll, and almost certainly not from a three-lock boll.

Boll Shape

The shape of a green boll is usually expressed in terms of "boll index" (maximum diameter of the boll expressed as a percentage of boll length). Similarly one could calculate an "internal lock index" (maximum width of the septum, *r*, expressed as a percentage of lock length). Theoretically, twice the "internal lock index" should equal the "boll index."

Dried bolls were collected from material available in the field. These included:

M 8—an Upland variety, similar to Deltapine, with exclusively four-lock bolls, round in shape with a boll index of about 80.

AS 15—an Egyptian (*barbadense*) inbred line with exclusively three-lock bolls. Bolls are oval, with a tapering apex, and a boll index of about 60.

RV—an interracial *hirsutum* hybrid, described in the previous section, with lock number varying from three to five and a boll index intermediate between those of M 8 and AS 15.

From the bolls collected, 10 segments of each variety were selected for measurement, an attempt being made to choose segments in which the boll walls were strongly recurved, matching as nearly as possible the recurved condition of the Tehuacan boll segment. The measurements are shown in Table 28. It can be seen that the internal lock index ($100r/L$) of the Tehuacan

Table 28. Comparative Average Measurements of 10 Dried Boll Segments Each of Three Cultivated Forms of Cotton (*in mm.*)

	Length of lock (L)	Width of septum (r)	Length of beak (b)	100 r/L	100 b/L
AS 15	30.09 ± 0.66	8.69 ± 0.22	7.58 ± 0.28	28.9	25.2
RV 3-lock	23.64 ± 1.08	8.25 ± 0.37	5.89 ± 0.47	34.9	24.9
RV 4-lock	30.70 ± 1.98	10.80 ± 0.29	6.40 ± 0.44	35.2	20.8
RV 5-lock	32.49 ± 1.55	11.67 ± 0.44	5.84 ± 0.39	35.9	18.0
M 8	24.44 ± 0.64	10.04 ± 0.30	6.59 ± 0.34	41.1	27.0
Tehuacan	33.30 –	11.75 –	9.75 –	35.3	29.3

Fig. 167. Dried segments of cotton bolls. The segment from Coxcatlan Cave, Zone XVI, is at extreme left of middle row. Top row: 3-lock bolls of AS 15 *(barbadense)*. Middle row: 4-lock (left) and 5-lock (right) bolls of RV *(hirsutum)*. Bottom row: 4-lock bolls of M 8 Upland *(hirsutum)*.

boll is smaller than that of M 8 and larger than that of AS 15. The index lies between the four- and five-lock values for RV. It appears that the Tehuacan boll was probably similar in shape to RV; that is, in its original state it would be ellipsoidal with a boll index of about 70.

In the same table, apical beak length is also compared. The Tehuacan boll has a long beak—considerably longer than in the other material examined and also relatively longer (*index 100b/L*). In general, bolls with a tapered apex tend to have longer beaks than do rounded bolls, but the conformity of the Tehuacan boll segment (see Fig. 167) does not indicate that the boll was tapered (maximum width of the septum is nearer to the apex than to the base of the boll). More probably the apex of the boll was rounded with an "abrupt" break.

In Fig. 168 are photographs of a range of cultivated forms of *hirsutum*. The upper row shows Central American types. The two bolls at the extreme left are types from Guatemala which resemble closely modern Upland bolls. The lower row consists of Mexican dooryard forms exclusively. The right-most boll in this row has what I would consider to be a good match for the

Fig. 168. Range of *hirsutum* bolls in present-day primitive cultivation. *Top row:* Central America. *Lower row:* Mexico; the boll at the far right probably has the same shape as the boll from Coxcatlan Cave.

shape of the Tehuacan boll, including the long beak. It was collected in Laureles, Michoacan, by Dr. L. L. Phillips.

Other Observations

In all New World cottons, both wild and cultivated, with which I am familiar, there is a sharp contrast in texture between the tough boll wall and the thinner, flexible, fibrous septum. In the completely dry boll the flexibility is lost and the septum often becomes brittle. In the Tehuacan boll segment the septum appears to be tougher than in present-day New World cottons. The edge of the septum (the thickest part) varies from 1.0 mm. to 1.8 mm. as compared with 0.7 mm. to 1.4 mm. in the M 8 material I have examined. Whether the thickness of the septum is due to accretion or impregnation of foreign material or represents a real difference from modern forms, I am unable to guess. Possibly it could be determined by sectioning the septum.

The inner surfaces of the Tehuacan boll segment, particularly in the less exposed parts or "pockets" toward the base and apex of the segment, seem to be covered with hairlike structures, while the ribs of the exposed septum and the reflexed surfaces of the boll wall appear to be smooth. It is possible that the "hairy" surface may be nothing more than the scuffing and fraying out of the fibrous tissues of which boll wall and septa are composed. The internal boll surfaces of all present-day New World cottons are smooth, but hairy septa are found in several wild relatives.

Toward the base of the segment, on both sides of the septum are a few long fibers which appear to have been trapped in the boll. They are flattened and convoluted and thus presumably could be small samples of lint from the original boll. It would probably be worthwhile to have these examined by a competent fiber technologist.

In some dried bolls the edge of the septum still bears traces of the funiculi ("stalks") to which the mature seeds were attached, and it is thus possible to estimate the number of seeds per lock. In the Tehuacan segment, unfortunately, the edge of the septum is worn away and only one attachment can be identified.

General Comments

The Tehuacan cotton boll is comparable in size to some of the largest *hirsutum* bolls in cultivation today. Many types in primitive cultivation today have considerably smaller bolls (see Fig. 168). However, we do find large-bolled types in apparently primitive cultivation—in *hirsutum*, the large-bolled types in Tuxtla and Acala, Mexico; in *barbadense*, the long kidney-seeded bolls which appear to be native to Central Brazil and the Guianas.

The Tehuacan boll was found at a cultural level that preceded settled cultivation, which would imply that the boll was borne on a wild plant. If true, this is a totally unexpected situation. All wild species of *Gossypium* today, including wild forms of the cultivated species, have small bolls with small seeds (boll size and seed size are highly correlated). The Tehuacan boll would be expected to have proportionately large seeds, and if the fibers trapped at the base of the seg-

ment are original, it had convoluted (i.e., true lint) hairs, distinct from the fibers of exclusively wild species.

Thus, if the boll segments are correctly assigned to Zone XVI, one must assume that about 5500 B.C. there was a wild form of Mexican cotton with an exceptionally large boll quite beyond the range of boll size in all other wild species today. However, I understand that the two segments were found at the back wall of the cave, in a disturbed area where stratigraphy was difficult to establish. Also, there is a gap of about 2000 years before other materials identifiable as cotton appeared; these were found in Zone D of San Marcos Cave (see Table 26 above). One wonders if the two segments may not have fallen into the refuse of Zone XVI from an overlying level and hence represent a type in primitive cultivation rather than a bona-fide wild form. In the absence of a radiocarbon date on the boll fragment itself, only the discovery of an independent sample of comparable age can settle the question satisfactorily.

ED. NOTE: Since the above was written, Dr. Stephens has had an opportunity to examine a second segment of cotton boll found next to the one he has described. The second specimen had been pickled for preservation. He notes that agreement between measurements on the pickled boll and similar measurements on the dry boll are not particularly good but observes that there would be variations between segments from the same boll. He also reported:

"In Segment I the inner surface of the segment had a furry appearance and I wondered whether this was due to hairs or 'scuffing' of the surface. The surface of Segment II appears quite smooth when wet—when it is surface dried, the fibrous surface curls up in places, giving the same surface appearance as in Segment I. I think it is quite clear that there are no hairs and that the 'furry' surface is due to scuffing of the long fibrous cells of which the lining of the lock is composed. They are often irregularly branched and pass into the structure of the wall.

"In Segment I the septum seemed to be thicker and tougher than in modern cultivated forms—it was not clear whether this was due to a heavier structure or impregnation during storage.

"In Segment II the septum is translucent and flexible in sharp contrast with the boll wall—as in modern cultivated cottons.

"On the whole I can find nothing which would be atypical in a present day cultivated *hirsutum* cotton. The size is comparable with that of a modern, commercial Upland variety, though probably relatively narrower (ellipsoidal rather than rounded). There are types in native cultivation today in Mexico which would appear to be very similar."

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CHAPTER 14

Analysis of the Tehuacan Coprolites

Eric O. Callen

THE DRY conditions which prevail in certain archaeological sites of the New World are responsible for preservation of botanical remains and of fecal material, both human and animal. Such desiccated material has been found repeatedly during the last fifty or sixty years in archaeological sites of North and South America, but it is only comparatively recently, with the development of new techniques, that its value has been realized. At first, only seeds and bones could be identified. Today, plant tissues of many kinds, as well as various animal and insect remains, can be identified with certainty.

Since coprolites contain the actual materials consumed, analysis of them can give a more precise picture of the actual diet of ancient peoples than has been possible before. Therefore, provided a sufficient number of coprolites are available, it should be possible to study changes in the diet from site to site and from culture to culture. It should also be possible to obtain information on subsistence activities and patterns of the inhabitants of a particular site or of the people of a particular culture. It will be the object of this chapter to try to answer such questions as fully as possible, using the evidence furnished by more than two hundred coprolites found in the Tehuacan excavations; 116 of these were determined to be of human origin. Other evidence concerning subsistence is discussed in the chapters on plant remains, on the three major agricultural plants, and on animal remains.

Methods and Techniques

In this study each portion of feces was considered to be one coprolite, whether large or small. Occasionally, however, one or two small pieces were considered to be one coprolite if they had been wrapped together in aluminum foil at the excavation and appeared to have derived from a single large piece.

Before treatment the coprolites were assigned successive numbers, starting at one, there being a separate series for each phase of the Tehuacan cultural sequence. Each coprolite was inspected and the following information recorded: (1) the location from which it came—cave, culture, level, and square; (2) general appearance, shape, size, and color; (3) possible identity of donor—human or animal; (4) any vegetal, animal, or mineral remains adhering to the surface and obviously not originally part of the coprolite, such as stones, twigs, or bits of reeds or grass; (5) any material incorporated in the coprolite which could be recognized from the exterior or broken surface, such as bones, seeds, and hair; (6) whether pock-marked with holes—usually the emergence holes of coprophagous (dung-inhabiting) insects.

Thereafter the coprolite was dropped into a wide-mouth, screw-topped, sixteen-ounce glass jar half-filled with a half-percent aqueous solution of trisodium phosphate. This chemical was used by Van Cleave and Ross (1947) to reclaim dried tapeworms, so that they became soft and pliable and regained their original size. Callen and Cameron (1955, 1960) successfully adapted this method to reconstitute coprolites a few years later. The coprolite was allowed to soak for a minimum of seventy-two hours, though more usually for a week or more, to insure maximum softening. With gentle shaking it would then fall apart.

Though many of the coprolites regained what must have been their original consistency, those that consisted largely of bone, hair, cartilage, and meat re-

mains remained hard, even after prolonged soaking. They had a dirty, claylike appearance and had to be broken open with scalpel and forceps.

When the coprolite was ready for analysis, the color of the liquid was noted, together with the presence or absence of a scum or "chemical skin" covering the surface and the smell, if any. After removal of most of the scum, the liquid was gently decanted, to be used later. The solid matter was then suspended in fresh water and visually inspected bit by bit with the naked eye, or by means of a low-power binocular microscope. Representative samples of all materials were transferred to clean water, to be mounted later. All bones and bone chips were extracted, washed in clean water, and embedded in phenolized glycerine jelly in vials.

After inspection, the remaining material plus the originally decanted liquid was poured into a conical flask with a small spout at one side of the neck. Benzene was added until the liquid was within a quarter inch of the side arm. Vigorous shaking for thirty seconds thoroughly mixed the two liquids and brought the solid matter into contact with the benzene. In theory, all insect cuticle wetted by benzene will float at the benzene-water interface, but in practice small pieces of cutinized plant material appear there as well. Thus the material obtained by carefully pouring off the top clear layer of benzene and collecting the interface may contain not only small insects, parts of insects, pupae, and larvae, but also small seeds, grass glumes, pollen grains, and other spores, as well as small pieces of epidermis and "chemical skin."

Representative samples were extracted from the benzene-water interface material and placed in fresh water. Thereafter, all extracted materials were mounted on microscope slides in phenolized glycerine jelly, with the benzene extracted material clearly marked as such. Usually a few small bones or bone chips were mounted, as well as a few chips of stone or grains of sand, if present. The remaining coprolite material was considered exhausted for the purpose of this analysis and was discarded.

In some previous analysis attempts were made to extract parasite eggs by means of salt-flotation tests (Marsh 1965). However, so much plant material, especially grass glumes and seeds, floated to the surface that any eggs that might have been present were completely obscured. The results were therefore negative. Attempts to keep the slides for even three weeks without their drying out were quite unsuccessful. I made no attempt, therefore, to subject the Tehuacan material to salt-flotation tests.

Before the actual mounting of the extracted material, the following information was recorded for each coprolite as the extraction was completed: (1) the color of the trisodium phosphate after the coprolite had been soaked, the smell when the jar was opened, the presence or absence of a "chemical skin," and whether or not fungus had started growing on the surface; (2) the presence or absence of seeds, in what amounts and of what type, as well as their possible identity; (3) the presence or absence of bone and its identity if possible; (4) the presence or absence of wood or stones (sand); (5) the different types of material present in the coprolite and their relative abundance; and (6) unusual material present.

Two card-index systems have been maintained. The first contains one card for each microscope slide, on which is recorded the identity of all the material on that slide. The second, a punch-card system, has one card for each piece of different material on each slide. Frequently four pieces of material were mounted on the same slide. If all four pieces were of identical material, say *Opuntia* epidermis, they would be represented by one punch card for that slide. If all differed from one another, they would be represented by four punch cards.

The ability of trisodium phosphate to reconstitute material, apparently to its natural size, raises the question of whether this "natural size" is actually smaller or somewhat larger than normal. This would be important if the identity of some pieces of material hinged on actual measurements. In order to find out, the seed and fruit epidermis of year-old, sun-dried, ripe chili peppers, (*Capsicum* spp.) of seven varieties, which had been bought in the town markets of Tehuacan and Coxcatlan, were soaked in water and in trisodium phosphate for a week. Other seeds from each sample were sown in pots in a greenhouse, in order to obtain fresh, ripe material for comparison. Statistical analysis of the measurements of epidermal cells, of seed size, and of seed coat (testa) cell size, showed that there was no difference between living material and dried material subjected to soaking in water or trisodium phosphate solution.

Each coprolite, after being described, was placed in a sixteen-ounce glass jar. The jar was then half-filled with the half-percent aqueous solution of trisodium phosphate, and the cap screwed on tightly to preserve any odors that might develop. Within thirty seconds after being immersed, some coprolites started leaking a brown color into the clear, colorless solution. Others took a little longer, but within ten minutes 95 percent of the coprolites began to color the liquid. The remaining 5 percent were putty- or ivory-colored coprolites

that consisted almost entirely of meat, hair, and bone. Three or four days of soaking were necessary for the liquid to develop the full color, ranging from a clear straw yellow through varying shades of brown to a deep, opaque orange-brown-black. After about a week of soaking, with the minimum of disturbance, a scum of varying texture frequently developed on the surface of the trisodium phosphate solution. Occasionally fungi developed on the scum, or chemical skin. The scum developed only when coprolites containing a mixture of meat and vegetal materials were soaked, not when the contents of the coprolite were almost entirely meat.

Subsequent analysis has shown that coprolites coloring the solution in which they were soaked an orange-brown-black color are almost certainly of human origin. The pale ivory coprolites consisting mainly of meat remains were interpreted as being of nonhuman origin. Other criteria used to distinguish human from animal coprolites were size and shape, smell, and content.

The question of pH (acid-base balance) was also investigated, and while many systems in the human body maintain a balance within narrow limits, this does not apply to feces. It proved impossible to find data about animal material, so that this line of investigation was negative.

The smells that developed from the soaked coprolites varied from a musty cave-soil smell, with a slight hint of a chemical, to the most intense fecal smell possible. Human coprolites containing a good deal of meat, and particularly those containing chili in any quantity, were the most malodorous. This at first suggested that perhaps intestinal bacteria had survived in spore form, had germinated during the soaking, and were continuing the job of putrefaction. However, Dr. H. P. A. Snead (1962), formerly of the National Institute of Medical Research, London, while investigating the longevity of bacteria, analyzed some coprolites about 3500 years old from Tamaulipas which I sent him. He found that they were absolutely sterile, as far as intestinal bacteria were concerned. His work showed that bacteria could survive only some two hundred to three hundred years in soil.

Therefore, the actual decomposition products of the food eaten, irrespective of the causal agent, must cause the smell. In the process of digestion, carbohydrates are broken down into simple sugars, and none of these has an unpleasant odor. Fats are broken down into fatty acids (which Snead 1962 recorded as being present in the coprolites he tested) but they too would not account for the unpleasant fecal smell. The third class of foods is proteins, which the body breaks down into the component amino acids. Some of these are stable, others unstable. Among these latter is tryptophan, which breaks down into 3-methyl indole, which is the substance responsible for the strong smell. This finally breaks down into the stable substance indole. Therefore, it appears that meat coprolites, assisted by the laxative powers of the chili pepper, which rushes them through the alimentary tract before all the amino acids have been extracted, are responsible for the offensive smell.

The human stomach empties in from two to four hours. Any materials eaten during that period will be churned up together, and in due course, will appear together in the same coprolite. Food normally takes twenty-four hours to pass through the alimentary tract, but may take up to forty-eight hours to do so. The intestine has many folds, in which pieces of material may be sidetracked for twelve hours or longer. Consequently, if only a single piece of a certain plant material turns up in a coprolite, it is quite likely to be a remnant of a previous meal. I might add that there is no reason to believe that the human body functioned differently 8,000 years ago.

No foolproof method of distinguishing between human and animal coprolites has been discovered. A combination of the following four criteria has been used: (1) the shape and size of the coprolite; (2) the color of the trisodium phosphate solution after the coprolite has been soaked for seventy-two hours or longer; (3) the smell; (4) the contents of the coprolite.

Identity of Hairs

Many of the coprolites containing meat and bone debris also contained mammal hairs, most of which it was possible to identify with varying degrees of certainty.* Mammal hairs have a definite structure, with a central core or medulla surrounded by an outer layer or cortex. Externally they show a distinctive scale pattern. The medulla contains air pockets or cavities, which are arranged in definite patterns. As the hair becomes older, the membranes separating these air pockets tend to break down and leave a continuous hollow in the hair. The identification of the hairs rested, therefore, on the following: (1) the width of

* I am greatly indebted to the following gentlemen who permitted me to obtain hairs as comparative material from Mesoamerican specimens in their care: Mr. P. M. Youngman, National Museum of Canada, Ottawa; Dr. J. C. Moore, Chicago Natural History Museum; Dr. George Goodman, American Museum of Natural History, New York; and Dr. Kent V. Flannery, Smithsonian Institution, formerly with the Tehuacan Project. I am also indebted to several student assistants in this work, particularly to Robin H. M. Cross, who was responsible for the bulk of the final hair determinations. This work has been aided by a grant from the National Research Council of Canada.

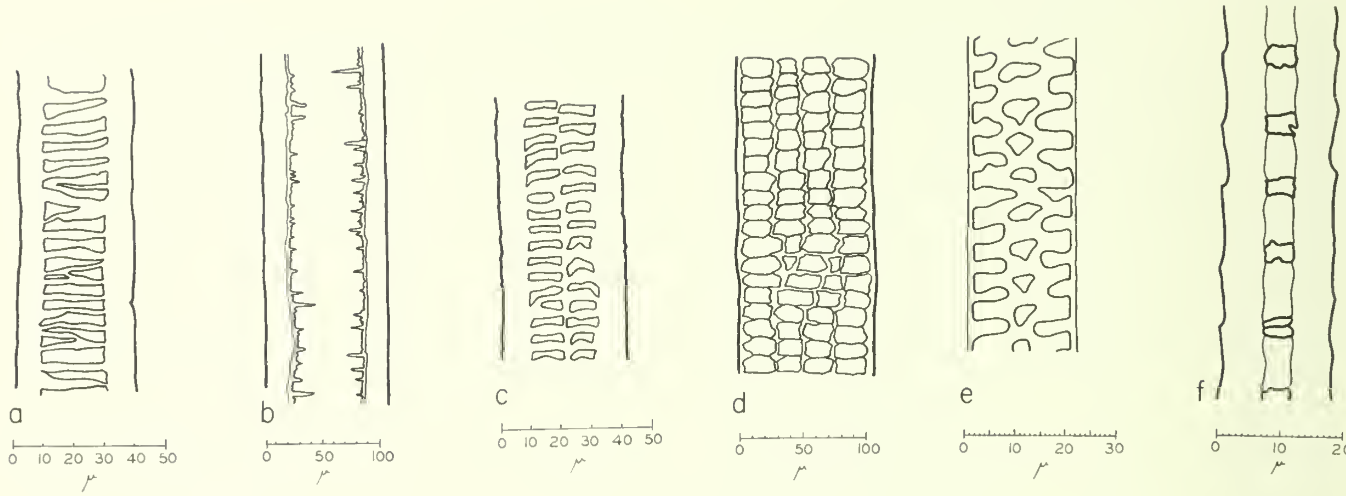


Fig. 169. Hairs identified in coprolites: *a*, *Bassariscus astutus*, ring-tailed cat, medium hair, Venta Salada coprolite. 2. *b*, *B. astutus*, coarse hair, Venta Salada coprolite 2. *c*, *Sylvilagus audubonii*, Audubon cottontail, medium hair, Venta Salada coprolite 62. *d*, *S. audubonii*, coarse hair, Venta Salada coprolite 62. *e*, *Dipodomys ordii obscurens*, Ord's kangaroo rat, medium hair, Venta Salada animal coprolite 28. *f*, *Lynx rufus*, bobcat, medium hair, Venta Salada coprolite 28.

the hair, (2) the width of the cortex, (3) the width of the medulla, (4) the pattern of the medulla, and (5) in fine hairs mostly, the external scale pattern. For most hairs the order of importance of the criteria was 4, 1, 3, and 2; for fine hairs the order was 5, 1, and 4.

Four types of hair were distinguishable: (*a*) coarse, the guard hairs; (*b*) medium, the normal fur; (*c*) fine, the under hair or fur; and (*d*) the whiskers. The medulla pattern was clearest in the medium hairs. In the coarse hairs the pattern had either developed further to give very distinctive patterns, or it was in the process of breaking down. The whiskers do not generally resemble the medulla pattern of the animal they come from, and the scale pattern is much less distinct, having been almost worn off in an adult animal. The whiskers closely resembled human hair.

Hairs of genera of animals differ from each other, though those of the genera of mice, for example, bear a general resemblance to each other, and are quite distinct from those of other genera. Two cottontails have been, and still are, common in the Tehuacan Valley, both belonging to the genus *Sylvilagus*. One is *S. cunicularius*, the Mexican cottontail; the other is *S. audubonii*, the Audubon cottontail. Surprisingly, the two sets of cottontail hairs are quite distinct from each other, though they do have a family resemblance.

The material to be examined had already been mounted in phenolized glycerine jelly on microscope slides. Attempts to extract the hairs and stain them before remounting had to be discontinued since the number of hairs involved was small, and some were usually lost in the course of each such operation. However, the glycerine jelly mounts showed up the medulla pattern very clearly, and the scale pattern on the fine hairs showed almost as well without staining.

Hairs of the following animals were found in the Tehuacan coprolites (nomenclature of *The Mammals of North America*, by Hall and Kelson, 1959): *Sylvilagus audubonii*, Audubon cottontail; *S. cunicularius*, Mexican cottontail; *Heterogeomys* sp., pocket gopher; *Dipodomys* sp., kangaroo rat; *Canis latrans*, coyote; *Bassariscus astutus*, ring-tailed cat; *Procyon lotor*, raccoon; *Lynx rufus*, bobcat; *Tayassu tajacu*, collared peccary; and *Odocoileus virginianus*, white-tailed deer.

Review of the Literature

Harshberger (1896) was perhaps the first to remark that undigested seeds extracted from human excrement might disclose which plants had been used for food. Apparently he did not himself report on any fecal analysis. Young (1910) noted quantities of sunflower seeds in human feces from Mammoth Cave in Kentucky, and noted especially in the feces of Salts Cave the presence of sunflower seeds, watermelon (?) seeds, and fragments of hickory shell. He concluded that the sunflower was a plant of major economic importance in the diet. Loud and Harrington (1929) found human and coyote feces in Lovelock Cave, Nevada, although the size of the feces (two inches in diameter) rather suggests something larger than human. In this case the

human diet was given as seeds, hulls, and tough plant fibers.

Volney Jones (1936) found seeds of marsh elder (*Iva*), canary grass (*Phalaris*), sunflower (*Helianthus*), and pigweed or goosefoot (*Chenopodium*), as well as fragments of acorn shells and hickory nuts, in human feces from Newt Kash Hollow Shelter, Kentucky. Feces taken from a desiccated body recovered from a bluff shelter in Arkansas were found by Wakefield and Dellinger (1936) to contain seeds of sumac (*Rhus*), acorns, and a fair amount of charcoal. R. L. Fonner (1951) gave a paper before the Michigan Academy of Science, Arts, and Letters, entitled "Human Feces as a Source of Archaeological Data," but this was never published. Also in 1951 he delivered another paper, "Plant Remains from the Proether Bluff Shelter," which is mentioned in the University of Michigan Occasional Contributions of the Museum of Anthropology. It too was never published. However, a more comprehensive account of the contents of human feces is that of Jennings in a preliminary report on Danger Cave, Utah, who recorded seeds of burro weed (*Allanrolfea*), the remains of desert bullrush (*Scirpus*), of mesquite pods (*Prosopis*), hair of deer or antelope, feathers, and small chips of bone (1953). Further work by Charles C. Sperry and by Robert L. Fonner was done on mammal feces from Danger Cave and from Juke Box Cave. This material was incorporated into Jennings' final Danger Cave report (1957). Webb and Baby (1957) examined human feces from some Kentucky caves, and reported finding seeds of sunflower (*Helianthus*) and goosefoot (*Chenopodium*), as well as bone, a feather, a grasshopper leg, and a fragment of beetle. MacNeish (1958) records breaking open fecal masses from the Ocampo Caves in the Mexican state of Tamaulipas and finding maguey fibers (*Agave*), squash seeds (*Cucurbita*), the remains of grasshopper, and snail shell fragments.

In 1960 Callen and Cameron reported on human feces from the Huaca Prieta, Peru, and were able to identify chili pepper (*Capsicum*) seeds and tissue, and tissue of the jack bean (*Canavalia*), the lima bean (*Phaseolus lunatus*), and squash (*Cucurbita*), as well as mussel, crab, starfish, and fish. In a subsequent paper, sea urchin, arthropod, snail, diatoms, and algae were added to that list (Callen 1965).

In a preliminary account of the contents of human feces from the Ocampo Caves of Tamaulipas, Mexico (Callen 1963), I identified maguey (*Agave*), aloe (*Aloe*), chili pepper (*Capsicum*), safflower (*Carthamnus*), sunflower (*Helianthus*), prickly pear cactus (*Opuntia*), lima bean (*Phaseolus*), and foxtail millet (*Setaria*), as well as bones of pygmy mouse (*Baiomys*), deer mouse (*Peromyscus*), lizard, snake, and deer. The coprolites also contained unidentified bone, eggshell, and feathers. Insects eaten included grasshoppers, bees, and wasps. In addition, I found remains of a number of other insects, dung feeders or parasites on dung feeders, which had colonized the feces after they had been deposited at the back of the caves. Among these were *Fannia scalaris*, the latrine fly; *Musca domestica*, the house fly; and *Drosophila*, the fruit fly. Also found were beetles, ants, spiders, mites, and termites. Bird (1943) identified remains of cereal and meat in offering bowls by the flies and beetles known to have a dietary affinity for these substances.

R. A. Yarnell examined feces from Salts Cave, Kentucky, and while confirming Young's (1910) identification of sunflower seeds and hickory shells, he was able to identify Young's questionable watermelon as squash, and to identify from seeds some fourteen other food plants. He also found fish scales, arthropod remains, and bone (Watson and Yarnell 1966). In 1964 Martin and Sharrock gave an account of a pollen analysis of human and nonhuman feces from various sites in the southwestern United States. Frequently some ten or more genera of plants were identified from each specimen tested, some of which were cultigens and others wild plants.

Finally, I supplemented my account of the insects from the Ocampo Caves, Tamaulipas (Marsh and Callen 1964, Callen 1965), by adding *Thylodrias contractus* Mots., the odd beetle, a scavenger of dried animal material, which appears to have followed man over the Bering Land Bridge as he migrated to the New World. I also have a preliminary account (Callen 1965) of the plants and animals identified from the human feces recovered from the caves of the Tehuacan Valley of

Table 29. Number of Coprolites per Phase and Cave

	Tc 35e		Tc 50		Tc 254		Tc 255		Tc 272		Tc 307	
	Human	Animal	Human	Animal	Human	Animal	Human	Animal	Human	Animal	Human	Animal
Venta Salada	5	21	9	44	–	–	–	1	–	–	–	–
Palo Blanco	7	3	33	17	8	11	–	–	11	6	–	–
Santa Maria	–	–	18	9	–	–	–	–	–	2	–	–
Ajalpan	–	–	–	–	2	3	–	–	–	–	–	–
Purron	–	–	–	–	–	–	–	–	–	–	–	–
Abejas	–	–	4	–	1	1	–	–	–	–	–	1
Coxcatlan	–	–	12	–	–	1	–	–	–	–	–	–
El Riego	–	–	6	1	–	–	–	–	–	–	–	–
Totals	12	24	82	71	11	16	0	1	11	8	0	1

Mexico. I will not list these materials here, since they form part of the substance of the pages that follow.

Sources of Material and Data

Coprolites were obtained from seven of the nine phases into which the Tehuacan cultural sequence is divided. All 237 specimens recovered have been processed, and representative fragments from them have been mounted on 6,904 microscope slides. The distribution of these materials in the Tehuacan cultural sequence appears in the accompanying tabulation. Bones

	Human		*Animal*	
	Cops.	*Slides*	*Cops.*	*Slides*
Venta Salada	14	282	66	2085
Palo Blanco	59	2132	37	735
Santa Maria	18	505	11	329
Ajalpan	2	64	3	28
Abejas	5	152	2	37
Coxcatlan	12	214	1	36
El Riego	6	296	1	9
Totals	116	3645	121	3259

and bone fragments and other materials too large to mount have been preserved in vials. These materials are presently housed in the coprolite laboratory of the Department of Plant Pathology of McGill University, at Macdonald College, Province of Quebec, Canada. They will be turned over to the Departamento de Prehistoria of the Instituto Nacional de Antropología e Historia in Mexico.

The 237 coprolites from the Tehuacan excavations were obtained from the following sites: El Riego Cave, East Niche (Tc 35e), Coxcatlan Cave (Tc 50), San Marcos Cave (Tc 254), Tecorral Cave (Tc 255), Purron Cave (Tc 272), and Abejas Cave (Tc 307). Details of the number of coprolites obtained from each cave and from each phase are given in Table 29. The totals are broken down as to origin, either animal or human. Altogether 116 coprolites were considered to be of human origin and 121 of animal origin. Well over half of the total sample came from a single site, Coxcatlan Cave.

El Riego Phase

Nine distinct levels from Coxcatlan Cave are assigned to this cultural phase, from earliest to latest, Zones XXII–XIV. A total of six human coprolites were recovered from the three latest of these levels, Zones XVI–XIV, and a single animal coprolite came from Zone XIX.

The principal plant materials in the human coprolites proved to be *Setaria* seeds, tissues from the starchy

Fig. 170. Setaria, greatly enlarged to show characteristic glumes.

root of the pochote tree (*Ceiba parvifolia* Rose), stem tissue and seeds of various species of cactus, and maguey (*Agave*) tissue.

Even though the six human coprolites came from three different zones, they all proved to have setaria seed or pochote root, or both, as dominant or co-dominant materials. Table 30 shows the more important materials mentioned above, plus the chili pepper (*Capsicum*) and mesquite (*Prosopis*).

Naturally it is the seeds and fruits in the diet which will indicate most reliably the season during which a cave was occupied. In this case, therefore, since setaria and other grasses including maize, chili pepper, cactus, mesquite, and the seeds of a composite (not sunflower) are all present, they indicate wet-season meals. The presence of grass flowers with stamens in Cop. 2 would indicate a mid-wet-season meal, while the others are probably late wet-season ones. Cop. 7, with no seeds and only the tissues of pochote root and maguey, could very well represent a dry-season meal. It should be noted also that remains of meat were included in four of the coprolites and that pochote and maguey were also included in wet-season meals.

Setaria, along with other grass seeds, was the main plant represented in the single coprolite from Zone XVI. There is one piece of leaf whose trichomes and stomata suggests maize. Taken together this may indicate that seeds of all grasses including wild maize were gathered, but that setaria was the most abundant

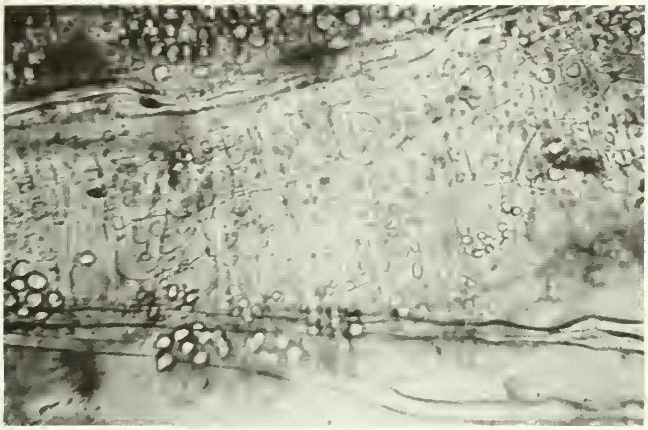


Fig. 171. Root of pochote shows starch grains, cells, and fiber.

one. The presence of some unidentifiable roasted plant tissue shows that the grass seeds were not eaten alone.

Setaria, with some other grass seeds, again formed the dominant material of the single coprolite from Zone XV, but with the addition of pochote root and cactus tissue.

The four coprolites from Zone XIV came from the same excavated square and contained the same principal materials as the coprolite from the previous zone, but with the addition of maguey tissue in some. The identification of chili pepper (*Capsicum*) seeds in Cop. 6 is notable, since this marks the earliest appearance of this plant in the coprolites. The presence of cactus seeds, including *Lemaireocereus,* in three of the coprolites is probably further indication that they represent wet-season meals. These four coprolites of Zone XIV show that a definite pattern of diet, based on wild plants growing near the cave, was adhered to by the inhabitants of Coxcatlan Cave at the end of the El Riego phase.

The grass seeds were gathered and prepared in such a way that many pieces of grass leaves were incorporated into the mixture eaten. This mixture appears to have been roasted (Cops. 1, 2), but not burned. In at least one other coprolite (no. 6), the maguey was very definitely roasted. As for the pochote root, larger pieces containing definitely undigested starch grains do not appear to have been roasted, but in most cases charred material is mixed with it. This rather suggests that after roots were dug up they were tossed on the fire for a few moments to burn off the outer layers. The heat of this charring, however, had not swollen the starch grains.

Four coprolites show evidence of meat, but there were no bones and no hairs by which this meat could be identified. Cop. 4, which did not appear to contain meat debris, contained fragments of egg shell, but they were too small to identify further.

In all the coprolites there were scraps of insect cuticle, probably from small insects which are unlikely to have formed part of the diet. A single head appears to be that of an ant (Cop. 4).

Summary

In Coxcatlan Cave during the El Riego phase the dietary pattern as revealed by the coprolites consisted of seeds of setaria and other grasses (including maize) and pochote root as the dominant materials, along with cactus and maguey and, generally, some meat. The setaria and the maguey tissue in some cases were definitely roasted. The pochote roots were apparently charred on the outside. The six surviving coprolites of the El Riego phase seem to represent wet-season meals.

The amount of setaria and other grass seed being used in Zone XIV suggests incipient cultivation and also that there may have been more surface water in the valley than there is today. Nevertheless, the inhabitants of Coxcatlan Cave must have traveled a good mile or so to reach the Rio Salado where the grasses probably grew. Other plant species identified in the coprolites were probably wild, but there is some possibility that maguey and *Opuntia,* which are easily propagated from offshoots or cuttings, could have been under primitive cultivation.

It is interesting to note that the seeds of setaria and other grasses were also found in small caches in the cave floors, suggesting that they were stored for future use and then forgotten. The seeds were also scattered —possibly accidentally—on the floors. A preliminary study of the breaking of the grains and glumes suggests a stirring or a pounding motion (both of which produce

Table 30. Contents of El Riego Phase Coprolites from Tc 50

Zone	Cop. no.	Setaria	Pochote	Maguey	Cactus	Mesquite	Chili pepper	Meat
XVI	1	‡				†		†
XV	2	‡	†		†			†
XIV	4	‡	‡		†*			
XIV	5	‡	‡		†*	†		†
XIV	6	‡	‡	†	†*		†	
XIV	7		‡	†				†

†Present.
‡Dominant or co-dominant.
*Tissue and seeds.

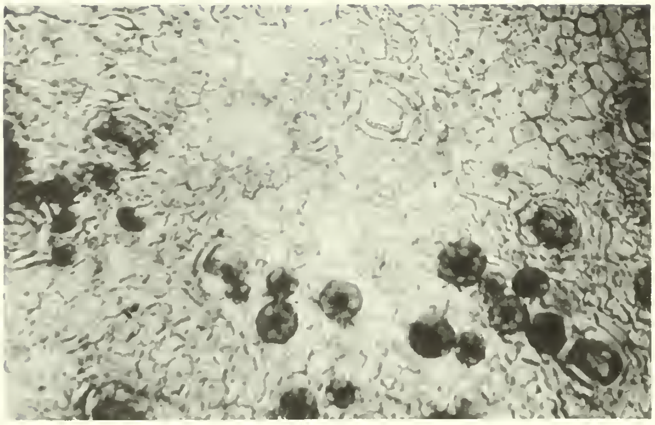


Fig. 172. The epidermis of *Opuntia*.

the same type of fractures), but not a rolling one. A stone mortar and pestle, recovered from the El Riego phase, was used for the study (Callen, in press).

Coxcatlan Phase

The twelve human coprolites representing this phase were recovered from Zones XIII-XI of Coxcatlan Cave. The single animal coprolite came from Zone F of San Marcos Cave. The principal plant materials in the human coprolites proved to be setaria seeds; the starchy root of pochote; stem tissue and fruits of cactus, including *Opuntia* and *Lemaireocereus;* maguey tissue; black sapote fruits; the fleshy leaves of yucca; and maize seeds.

The single coprolite (no. 5) from Zone XIII contained pochote root, setaria seeds, what appeared to be part of a single grain of maize, and meat. If eaten fresh, the setaria and maize would represent a late wet-season meal.

Zone XII is also represented by a single coprolite (no. 7). Maguey and pochote tissues are present in about equal quantities along with meat. The lack of other materials would seem to indicate a dry-season meal.

The remaining coprolites are from Zone XI and can be subdivided according to different levels within the zone. Coprolites 6, 14, and 15 came from the same level. All contained a large amount of pochote root tissue. However, Cop. 14 also contained black sapote (*Diospyros)* as co-dominant material, as well as a single setaria seed, some maguey tissue, and meat. The fruit of the black sapote ripens in the fall, and its presence definitely indicates a late wet-season or early dry-season meal. Cop. 15 contained a little black-sapote tissue as well as cactus, meat, and two small unidentified seeds—a combination that indicates the late wet or early dry season. Cop. 6 contained, in addition to pochote tissue, several kinds of seeds and the remains of a caterpillar. The seeds would indicate a wet-season meal. It is interesting to note that black sapote first appears in the coprolites in exactly the same zone in which it first appears among the plant remains from the refuse (Chapter 12).

Cops. 8–10, from another level of Zone XI, also had pochote root tissue as a dominant material, with setaria seed co-dominant in Cop. 8 and *Lemaireocereus* tissue co-dominant in Cop. 10. Setaria was present in Cops. 9 and 10 along with cactus tissue and (in Cop. 9) also some cactus seeds. Cops. 9 and 10 may represent an early dry-season diet. However, Cop. 8, containing pochote root, setaria, and meat, rather suggests a wet-season meal, if the setaria were eaten fresh, as does Cop. 4, with setaria dominant among pochote tissue and meat. Cop. 16, the final sample from this level, contained a dominant amount of setaria along with meat, black-sapote remains, and chili pepper (*Capsicum*) tissue. This combination represents a late wet-season or an early dry-season meal.

Cops. 11 and 12, from a third level of Zone XI, contained pochote root tissue as dominant plant material, with meat co-dominant in Cop. 12. The presence of setaria seeds in both, along with maguey and cactus tissue, probably indicates early dry-season meals.

The single coprolite from Zone XIII showed the same pattern of contents established in coprolites from Zone XIV of the El Riego phase, with pochote root tissue the dominant vegetal material among setaria and other grass seeds, including part of a maize kernel. Cop. 7 from Zone XII demonstrated a common dry-season meal pattern that continued into the Santa Maria phase —a mixture of maguey, pochote root, and meat.

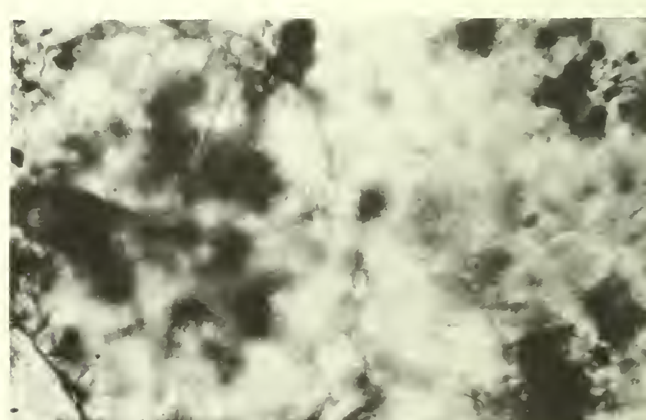


Fig. 173. Tissue of *Lemaireocereus*. Note large crystal at left.

Table 31. Contents of Coxcatlan Phase Coprolites from Tc 50

Zone	Cop. no.	Setaria	Pochote	Maguey	Lemaireocereus	Other cactus	Chili pepper	Black sapote	Maize	Meat
XIII	5	†	‡						†	†
XII	7		‡	‡						†
XI										
level 7	6	†	‡		†	†*				†
	14	†	‡	†				‡		†
	15		‡			†*		†		†
level 6	4	‡	†							†
	8	‡	‡							†
	9	†	‡	†		†*				†
	10	†	‡		‡	†*				†
	16	‡					†	†		†
level 4	11	†	‡	†						†
	12	†	‡			†*				‡

†Present.
‡Dominant or co-dominant.
*Tissue and seeds.

The Zone XI coprolites, like those of Zone XIII, showed the pattern carried over from El Riego times. Pochote root is the dominant or co-dominant material of the diet, appearing along with other plant tissue. There is only a little cereal in the form of setaria and other grass seed. The other plant tissue might be *Lemaireocereus*, *Opuntia*, or maguey. Usually some meat is included in the diet.

The two coprolites from Zones XIII and XII both contained charred material in small quantities. Some of the pochote tissue in both was obviously charred. It seems certain that, as in El Riego times, the pochote roots were flung on the embers before being eaten, in order to burn off the outer corky layers. Some of the maguey epidermis in Cop. 7 also had definitely been roasted.

The eight coprolites from Zone XI that contained charred material also contained pochote root tissue. The one that lacked pochote (Cop. 16) contained very definitely roasted and charred setaria seeds, as well as some other unidentifiable charred plant material. The co-dominant pochote and setaria materials in Cop. 8 were definitely roasted. Although meat was present in most coprolites, only in Cop. 12 were there definite signs that it had been roasted. The seeds of *Lemaireocereus* from Cop. 6 were definitely roasted, and in fact were almost charred.

Meat debris was present in the two coprolites from Zones XII and XIII, but there were no bones or hairs to indicate its origin. In the Zone XI coprolites, meat debris was present in all except Cop. 8. This does not mean that large quantities had been eaten at each meal, but rather that there were traces of meat in each coprolite. There were no bones or hairs by which the very definitely roasted meat of Cop. 12 could be identified. The only coprolite with bones was Cop. 11, a pochote and maguey meal, where the bone pieces suggested an animal larger than a rabbit. A few hairs were present in Cop. 16 which proved to come from an Audubon cottontail.

Insect remains were recovered from four coprolites of Zone XI. Cop. 4 contained pupae of a coprophagous insect. Cop. 6 contained the remains of a medium-sized butterfly caterpillar, which was apparently responsible for much of the meat debris found in the coprolite. It also contained an entire small insect, as yet unidentified. Cop. 11 contained a *Drosophila*, or fruit fly, larva, and some insect cuticle. Cop. 12 contained many ant heads, some ticks, and a number of both small and medium-sized larvae of unknown type. This was the coprolite that also contained the roasted meat. The ant heads present a tantalizing question: Are they from honey-pot ants? A special study of ant heads at a later date may answer this question. Nothing suggesting the remains of the swollen abdomen of ants was found. Cop. 16 also contained a little insect cuticle of unknown origin.

Summary

Coxcatlan Cave during the Coxcatlan phase was occupied in both the wet and dry seasons. The single coprolite from Zone XIII probably represented a wet-season meal. The one from Zone XII, on the other hand, was probably the residue of a dry-season meal. The other coprolites, all from Zone XI, represented meals from both wet and dry seasons. The late wet-season diet of pochote root and setaria noted in late El Riego times continued in use. At the same time a dry-season diet of maguey and pochote root, along with some meat, became evident during the Coxcatlan phase.

Pochote root was the most important single plant material found in the human coprolites from the Coxcatlan phase. The pochote tree (*Ceiba parvifolia*) grows wild in the valley, mainly in the thorn-scrub vegetation on the eastern side. *Lemaireocereus* and *Opuntia* are also native to the vegetation around Coxcatlan Cave. However, setaria, the second most important plant in the diet during this phase, must have grown along the Rio Salado, a mile or two from Coxcatlan Cave. Maguey seems to have played a much less important role in the diet of this phase than the various cacti did.

The black sapote (*Diospyros*) appears for the first time in the coprolites of this phase. In fact, the black sapote must have been brought into the Tehuacan Valley at this time. Chili pepper appears again in this phase and may have come from a cultivated plant. Surprisingly, none of the annual plants believed to have been first cultivated—beans (*Phaseolus*) and squash (*Cucurbita*)—appear in the human coprolites of this phase.*

Methods of preparing food do not seem to have changed. In this period, too, the pochote roots apparently were flung on the fire to burn off the outer layers, but the heat did not affect the starch grains in the center. As much of the starch was still contained within the cells, there appears to have been no beating to break up the cells to allow the starch to escape. The setaria grains and glumes, on the other hand, had been broken down mechanically, probably with mortar and pestle as in the previous phase. The resultant material had been roasted and even charred a little—or perhaps the seeds were first parched for better storage and were later ground. *Lemaireocereus* seeds also were roasted, and maguey was roasted occasionally. In only one coprolite was there evidence of the roasting of meat. There was no evidence of food prepared by boiling.

Abejas Phase

This phase is represented by seven coprolites, five of which are of human origin and two of animal origin. Four of the human coprolites came from Zones IX and VIII of Coxcatlan Cave. One human and one animal coprolite were recovered from Zone D of San Marcos Cave. A single animal coprolite came from Abejas Cave.

Coxcatlan Cave

The principal plant materials in the human coprolites from this site proved to be cactus tissue, including *Opuntia* tissue; maguey tissue; pochote root tissue; and squash (*Cucurbita*) fruit tissue and seeds.

Cop. 5 from Zone IX contained mainly cactus tissue, including *Opuntia*, and meat debris. There was also some maguey tissue, a very little pochote root tissue, and a small sliver of wood. The contents together indicate a dry-season meal. Cop. 7, from the same zone, consisted of *Cucurbita* material, with small scraps of charred grass or cane epidermis, plus a little meat debris. This combination suggests a late wet-season or early dry-season meal.

Although pochote root played an important role in the diet of the El Riego and Coxcatlan phases, it is not so prominent in coprolites of the Abejas phase, possibly because the sample is too small. In Zone IX two kinds of cactus and a little maguey were the plants in one meal, and squash was almost entirely the substance of the other. It is worth noting that the whole squash had been eaten, as both fruit tissue and chewed fragments of seed were found.

In Zone VIII the combination in Cop. 4 was maguey, cactus, a very little pochote root tissue, and some meat —a diet that was firmly established by Santa Maria times. Cop. 6 from this zone contained predominantly meat tissue with a few fragments of mesquite and other tree-legume pods. The pods indicate a wet-season meal.

The *Cucurbita* in Cop. 7 from Zone IX had definitely been roasted. Both the exocarp and mesocarp showed the typical browning associated with this type of cooking. Cop. 5, from the same zone, contained roasted maguey tissue and some charred *Opuntia* tissue which contained concentrated amounts of druses, suggesting that the subepidermal tissues had been scraped together for eating purposes and the epidermis discarded, as none was present in the coprolite. Both coprolites in Zone VIII contained roasted or charred plant material which could not be identified. Perhaps some charred bits of pochote root were eaten with the uncharred tissue in Cop. 4.

Bone occurred in three of the four coprolites. The small bones in Cop. 5 seem definitely to be mouse bones, but there are no hairs to confirm this identification. In Cop. 6 the bone chips and fragments are those of an animal larger than a rabbit, but again no hairs were present to help identify the victim.

Table 32. Contents of Abejas Phase Coprolites

Site and zone	Cop. no.	Pochote	Maguey	Opuntia	Other cactus	Mesquite	Black sapote	Cucurbita	Maize leaf	Meat
Tc 50, IX	5	†	†	†	‡		†			†
	7							‡		†
Tc 50, VIII	4	†	‡		†	†			†	‡
	6					†				‡
Tc 254, D	3		†		‡		†			‡

†Present.
‡Dominant or co-dominant.

* A seed identified as *Cucurbita mixta* (see Chapter 11 above) appears in a coprolite from Zone XIII. This coprolite forms part of the exhibition of the archaeological museum in Tehuacan and therefore was not available for this study.—ED.

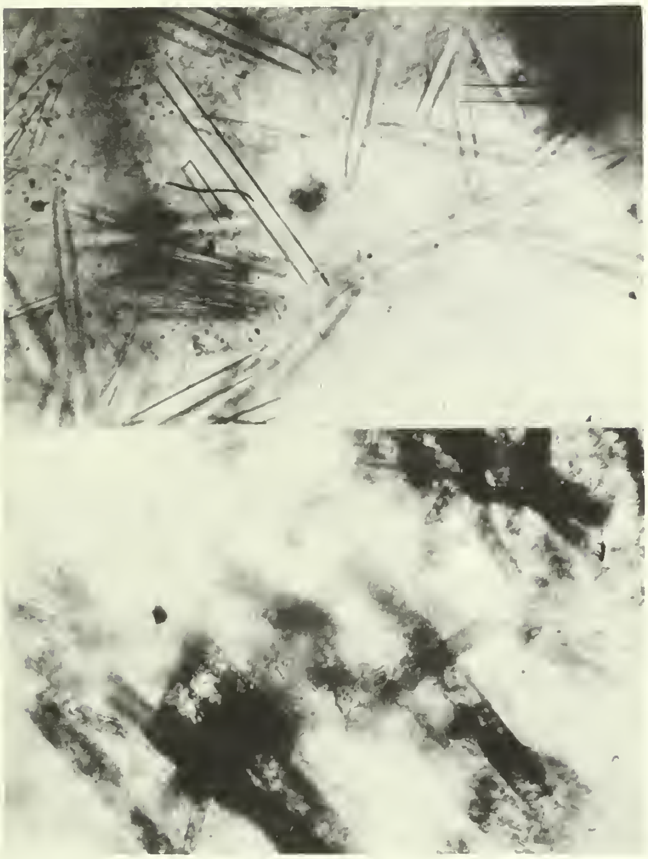


Fig. 174. Maguey tissue. *Above:* unroasted; note clear elongated crystals. *Below:* roasted, with shattered crystals.

The coprolites from Coxcatlan Cave in the Abejas phase, then, suggest mainly a dry-season diet in which pochote root did not play a major role. This diet, consisting mainly of maguey and cactus tissues, continued to be used in succeeding phases. *Cucurbita* appeared for the first time in the coprolites which I examined. The whole fruit was roasted and eaten, including the seeds.

San Marcos Cave

The principal plant materials recovered from the human coprolite in Zone D were cactus tissue, grass leaves, and maguey tissue. The presence of a very few grass and *Opuntia* seeds suggests a late wet-season or even an early dry-season meal, a diagnosis confirmed by the presence of black-sapote tissue. The cactus and maguey combination is the fairly standard dry-season diet noted in the Coxcatlan Cave coprolites of this period. The presence of the few seeds, however, would make it either a late wet-season or early dry-season meal here.

Meat was eaten with this meal, but there were no bones or hairs to give a clue as to the identity of the animal. None of the foods eaten showed evidence of charring or roasting or other indication of preparation.

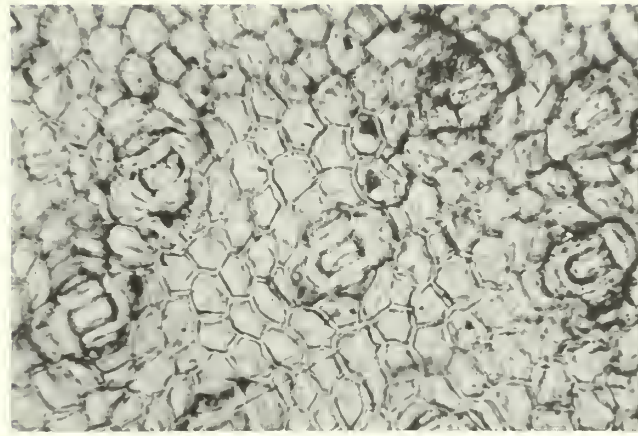


Fig. 175. Maguey epidermis.

The only insect remains recovered from the San Marcos coprolites, human and animal, were some chitin of unknown origin and an ant head and leg.

Summary

Human coprolites representing the Abejas phase were recovered from two caves. They represent a diet of maguey and meat, supplemented by cactus. This combination, as a dry-season diet, persists into Santa Maria times. Pochote root tissue was not prominent, perhaps because the number of coprolites was too small for an adequate sample of the diet.

Roasting appears to have been the main method of cooking. The squash in Cop. 7 had been roasted, although the seeds were quite untouched by the cooking. The seeds had been chewed—one of the very few occasions when they have been found in this condition in the Tehuacan coprolites. Maguey and *Opuntia* had also been roasted. The absence of the *Opuntia* epidermis suggests that the starchy interior tissue of the stems were eaten and the charred epidermis discarded. The subepidermal layer of druses was obviously scraped together before eating. There was no evidence of roasting of meat.

Ajalpan Phase

All five coprolites representing the Ajalpan phase are from San Marcos Cave.* Two are of human origin and three of animal origin.

* No material representing this phase was recovered from Coxcatlan Cave, which was unoccupied during this early Formative period.—ED.

The principal plant materials in the two human coprolites proved to be maguey tissue, *Lemaireocereus* seeds, and black sapote fruits. Both coprolites contained roasted and charred maguey tissue as dominant material, along with *Lemaireocereus* and other cactus seeds. One also contained some black sapote remains and an unidentified seed, indicating a late wet-season meal, or perhaps an early dry-season one. The other contained some additional unidentifiable plant material, but it too was most likely a late wet-season meal. The maguey tissue had been roasted and charred, but the other plant material was apparently eaten raw.

In one coprolite the teeth and lower jaw of a mouse were found, along with other bones. The other coprolite contained meat debris but no bones or hair by which the meat could be identified. There were also a few insect remains: material that looked like pseudoscorpion chitin, as well as insect chitin which could not be identified.

Summary

Plants generally regarded as cultivars which were eaten during this phase include maize and black sapote. *Lemaireocereus* and maguey were probably from wild plants. The almost complete absence of setaria seeds and pochote root in the Ajalpan zone of San Marcos Cave, as in the Abejas levels of both San Marcos and Coxcatlan caves, is of interest, but the inadequateness of the sample makes theorizing unsatisfactory.

With regard to food preparation, maguey was roasted and charred as in previous cultures. The presence of mouse bones but no hairs might indicate that the animals were skinned or singed before they were eaten.

Santa Maria Phase

All but two of the twenty-nine coprolites from this phase were recovered from Zone VII of Coxcatlan Cave. Of these, eighteen are of human origin and nine of animal origin. The two others, from Purron Cave, are of animal origin.

The principal plant materials in the human coprolites proved to be setaria seeds, tissue of pochote root and maguey, *Lemaireocereus* and other cactus tissue, black-sapote fruit, mesquite pods, and the starchy tissue of what appears to be cassava (*Manihot*).

Zone VII is the only Coxcatlan Cave component of the Santa Maria phase. It was excavated in eight levels, five of which contained human coprolites. In level 8 there was a single coprolite (no. 12) with pochote root and *Lemaireocereus* as co-dominant materials. Cop. 21 from another level had the same co-dominants. In the former there was also a little *Cucurbita* tissue, in the latter a little setaria. These would probably represent late wet-season meals.

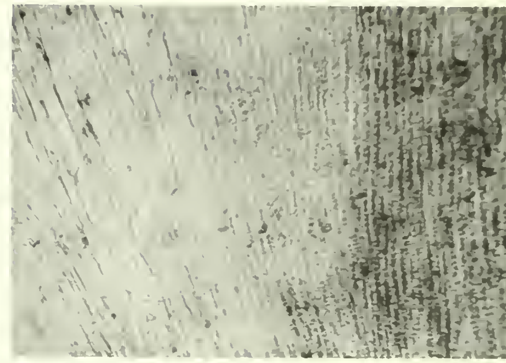


Fig. 176. Maize pericarp shows few distinctive features.

In level 7 there were two coprolites. Cop. 1 contained *Lemaireocereus* and setaria as co-dominant materials, and *Physalis* (ground cherry) as sub-dominant. It also contained several other seeds, such as bean and amaranth. This combination points to a wet-season meal. Cop. 14, by the time it reached the laboratory, had already broken down into dust. It contained *Cucurbita*, but no setaria seed or pochote root. Some tree-legume pod tissue and maize pericarp suggest a wet-season meal.

In the next level there were two coprolites (nos. 2 and 11) with eight plants in common. Four of these plants were represented by seeds and fruits. Setaria was the dominant material in Cop. 2 and pochote root in Cop. 11 with maize subdominant, but both must have been wet-season meals.

From level 5 eight coprolites were recovered, of which five came from the same square. Here pochote root was dominant or co-dominant along with setaria or cactus (including *Lemaireocereus*). Black-sapote fruits, mesquite pods, and various seeds indicate late wet-season meals as well.

The five coprolites from level 4, containing setaria, *Lemaireocereus*, mesquite, black sapote, and other seeds, all must have been late wet-season meals.

It would appear, then, that Zone VII was occupied at least during the wet season.

With regard to the use of plants in this phase, fair amounts of setaria were still eaten. It was the dominant or co-dominant material in five coprolites and was present in all the others except one. It was eaten in combination with pochote root or maguey. This has no seasonal significance, as black sapote and *Lemaireocereus* were eaten with both combinations, which

Table 33. Contents of Selected Santa Maria Phase Coprolites from Tc 50, Zone VII

Level	Cop. no.	Setaria	Pochote	Maguey	Lemaireocereus	Other cactus	Mesquite	Other seeds	Black sapote	Meat
4	17	‡		†			†	†		†
	18	‡		†					†	†
	19	†		‡			†		‡	†
	20				‡		†		†	
	21	†			‡		†			†
5	3	‡	‡							
	4	‡	‡				†	†	†	
	5	‡	†				†		†	
	6	†	‡				†	†		†
	7	†	‡			†*			†	†
	8	†	‡			‡	†	†		†
	9	†	‡			‡*	†		†	†
	10	†	‡			†*				†

†Present.
‡Dominant or co-dominant.
*Tissue and seeds.

means they come from late wet-season meals, or possibly meals of the early dry-season. It is worth noting that black sapote and *Lemaireocereus* had by now become regular items of the diet in Coxcatlan Cave.

The continued use of pochote root as the dominant or co-dominant material in a meal in what we shall call the "cave diet," is of interest, as this must represent a diet based on less sophisticated plants. Squash, and particularly maize, had become important cultigens by this time, but they make only a token appearance in the coprolites.*

The appearance of an epidermis resembling that of *Physalis* fruits is of interest here, as is a starchy tissue that greatly resembles *Manihot* (cassava). The former species does not appear among the refuse remains until the subsequent phase.

The pattern of food preparation noted in El Riego and Coxcatlan times is still maintained in this period. The pochote root, still a dominant food in most coprolites, shows definite evidence of roasting and charring. The setaria in Cop. 1 had been charred, and in some of the others there is a suggestion that it had been roasted.

* Evidence provided by the plant remains among the refuse indicates that maize was probably used universally by the Santa Maria phase. If maize kernels were boiled with ashes or lime to remove the pericarp and the resulting hulled corn ground to a very fine meal, or paste, as in the making of tortillas in historic time, there would be no identifiable trace to appear in the coprolites.—ED.

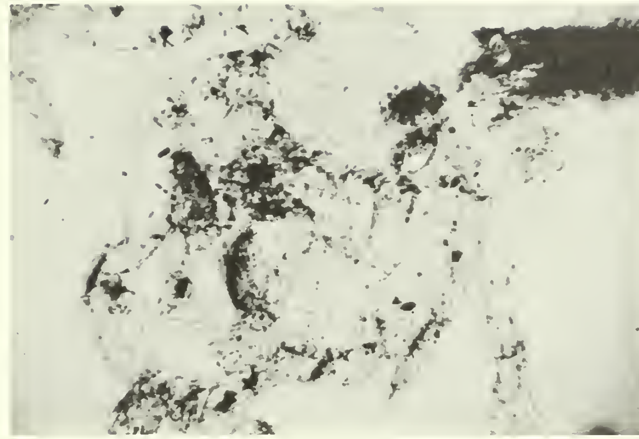


Fig. 177. Bird or biting louse (Mallophaga).

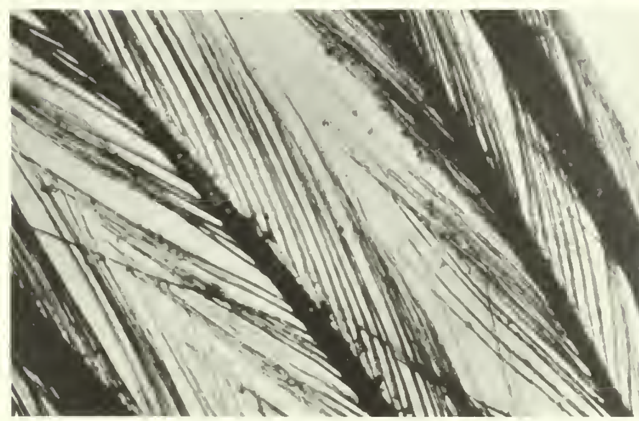


Fig. 178. Feather, possibly of a turkey.

Five of the eighteen coprolites lacked remains of meat. Of the five, one was a wet-season coprolite containing fruits and seeds; another was probably a dry-season one containing chiefly *Lemaireocereus* tissue. Cops. 6 and 8 contained mouse bones, including vertebrae, but no hairs were present to confirm the diagnosis. Cop. 11 contained bone chips of an animal larger than a rabbit, but again no hairs were present.

Meat debris of insect origin can generally be distinguished from that of mammal origin, and some was present in the human coprolites.

Feathers, possibly those of turkey, appear in two coprolites, but chiefly in Cop. 14, along with meat debris and unidentified bone.

The insect remains recovered from the human and animal coprolites were mainly in the form of pupae of dung-inhabiting insects. The remains of small adult beetles were recovered from two coprolites, *Drosophila*

larvae from two others, and the larva of *Fannia scalaris*, the latrine fly, from another. Chewing lice were recovered from one human coprolite (no. 14), containing bird remains, and from one animal coprolite (no. 25). These lice belong to the Order Mallophaga, which generally parasitize birds.

In summary the coprolites from Zone VII of Coxcatlan Cave suggest: (1) a wet-season diet of a variety of fruits and seeds (including setaria) with a little plant tissue and occasionally supplemented with meat; (2) an early dry-season diet with an occasional fruit or a few seeds, but mainly plant tissues and meat. It appears to have been the usual custom to eat maguey with meat; frequently such a meal was supplemented by pochote root. Setaria and other grasses were probably eaten when ripe. *Cucurbita* and maize appeared only three times each in eighteen coprolites, tree-legume pods (other than mesquite) also appeared three times, and amaranth and chili pepper twice each.

Summary

The pochote root and setaria diet, seen in coprolites from the El Riego, Coxcatlan, and Abejas phases of Coxcatlan Cave, is still represented in this phase, even after the lapse of 2000 years or so during which the cave apparently was unoccupied. *Lemaireocereus* and the black sapote, which had appeared in the coprolites in the Coxcatlan phase, are still important plants in the diet. On the other hand, maguey and cactus, which had constituted the major portion of the diet represented by coprolites from the Abejas and Ajalpan phases of San Marcos Cave, play a relatively unimportant role in the diet during the Santa Maria phase represented by coprolites from Coxcatlan Cave.

Maize and the cucurbits have an insignificant role in the diet, which is therefore designated the "cave diet," to distinguish it from the diet which must have prevailed in the villages and towns at this period. *Physalis* and what is apparently cassava make their first appearance here in the coprolites.

The meat in coprolites cannot always be identified because hairs, on which identification is based, may not be present. However, mouse bones were identified several times. In a few other coprolites chips of bones indicated animals larger than rabbits. Feathers from two coprolites are possibly those of turkey. Identified insects include chewing lice (*Mallophaga*), beetles, and larvae of *Drosophila* and *Fannia*, and pupae of other insects.

The pattern of roasting, first noted in coprolites of the El Riego phase, is maintained. This means that pochote root still shows definite evidence of roasting and charring, and that at least occasionally setaria seed is still parched. Although maguey was roasted, it does not appear frequently in this phase.

Physalis was apparently eaten raw, as a fruit, but at times evidence of roasting seemed to be present. The material identified as cassava showed no sign of being roasted, nor was there evidence of the roasting of meat. The absence of hairs from coprolites containing meat debris and bone suggests that skinning had become the fashion and that greater care was now taken in the skinning.

Palo Blanco Phase

Secular and religious cities had come into existence at this period, and the caves were probably used only occasionally for human habitation. It is therefore not surprising to discover that a large proportion of the coprolites recovered from the caves are of nonhuman origin. Fifty-nine coprolites of human origin were recovered, of which thirty-three came from Coxcatlan Cave, eight from San Marcos Cave, seven from El Riego Cave, and eleven from Purron Cave. Thirty-seven animal coprolites were recovered.

Coxcatlan Cave

The principal plant materials from the thirty-four human coprolites proved to be the starchy root of pochote, setaria seeds, maguey tissue, black sapote fruit tissue, *Opuntia* tissue and fruit, and *Lemaireocereus* tissue and fruit. This phase is represented by Zones VI, V, and IV of Coxcatlan Cave, from all of which coprolites were secured.

Twenty-one human coprolites were found in Zone VI, of which nineteen were from the same square and level. In view of the contents, they must represent the meals of sundry individuals over a period of several months. Pochote root tissues formed the dominant or co-dominant material in twelve of them. Although setaria seed was present in all but two, it was dominant in only two of the nineteen (Table 34). These latter two probably represent late wet-season meals. Those containing black sapote represent either late wet-season or early dry-season meals. The cactus seeds present in a number of these coprolites again indicate wet-season meals: *Lemaireocereus* possibly early to middle wet season, and *Opuntia* possibly late wet season. *Opuntia*, however, is not considered such a reliable indicator as other cacti, because it fruits over a long period. Cop. 42, also from Zone VI, contained cactus tissue without seeds and no meat, and was probably a dry-season meal. Cop. 81 consisted mainly of mesquite pods and

Table 34. Contents of Selected Palo Blanco Phase Coprolites

Site and zone	Cop. no.	Setaria	Pochote	Maguey	Opuntia	Lemaireocereus	Other cactus	Mesquite	Chili pepper	Black sapote	Maize	Composite	Other seeds	Meat
Tc 35e, D	45			‡										†
	49						†						‡	
	50						‡					†		‡
	51			‡					†		†		†	†
	52			‡							†			†
	53			†					†			†	‡	‡
	86			‡					†				†	†
Tc 50, VI	19		‡	†										†
	20	‡	†											
	21	†	‡				†							
	22	†	‡				†*			†				†
	23	†	‡	†						‡				†
	24	‡	†				†*							†
	25	†					†			‡				†
	26	†	†				‡*			‡				†
	27	†	‡				†							†
	28	†	†	†						‡				†
	29	†		‡										†
	30	†	‡	‡			†*							†
	31		‡	†			†*							†
	32	†	†	‡			†							
	33	†	‡	†			†*							†
	34	†	‡				†							†
	35	†	‡	†			†			†				†
	36	†	‡	†			†*			†				†
	37	†	‡	†			†*			†				†
Tc 254, B	6			‡		†*	†	†					†	†
	92			‡			†	†					†	
	12			‡			†							†
	87						‡*	‡						
	88			‡										†
	90			‡										†
	91			‡										
Tc 272, B	55			†	†	†	‡		†					‡
	56			‡	‡								†	†
	57			‡	†	†	†						†	†
	58			†					‡				†	‡
	68			‡	†				†				†	‡
Tc 50, IV	95	†	‡		†	†	‡							†
	96	†	‡		†	†	‡							
	97	†	‡		‡		†							
	98	†	‡		‡									†
	99		†		†									‡

†Present.
‡Dominant or co-dominant.
*Tissue and seeds.

contained no meat and was most likely a wet-season meal.

Zone V contained five human coprolites, two of which represented maguey meals–one maguey alone, the other maguey with fruit and meat. The former was probably a dry-season meal; the fruit in the latter points to the late wet or early dry season. A third coprolite consisted of cactus tissue, plus five different types of seeds, none in great numbers. This meal would represent the late wet or early dry season.

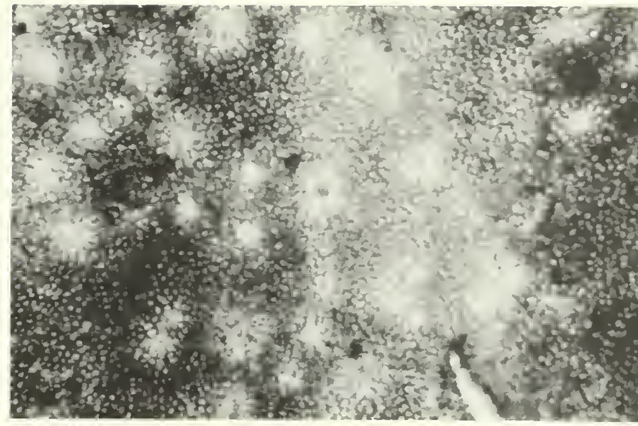


Fig. 179. *Cucurbita* exocarp.

The other two coprolites of Zone V are of particular interest. Cop. 94 contained *Phaseolus* (common bean), pineapple, chopped lily buds, and roasted maguey tissue and had a smell which suggested that large quantities of "beer" had been consumed. The flower buds may have been those of maguey or yucca, which are eaten today. Cop. 74 contained maize and roasted maguey tissue as co-dominant materials, plus squash and cactus tissues. The meal represented by Cop. 94 had very likely not been eaten in the cave, but rather at home the day before. That represented by Cop. 74 had perhaps been eaten away from home, but with maize and squash brought from home and supplemented by semidomesticated or wild maguey and cactus tissues. This suggests someone more than twenty-four hours away from home, most probably nearer thirty-six hours.

Zone IV contained six coprolites, five of them from the same location. Pochote root and cactus were co-dominant materials in four (Table 34). The presence of small quantities of setaria in all four suggests a late wet-season or early dry-season meal. The fact that two of these coprolites contained at least three different types of cacti suggests a party living off the land. The two other coprolites from Zone IV both suggest dry-season meals. Maguey and pochote tissue were co-dominant materials, along with meat, some tree-legume remains, and empty grass glumes. The other coprolite contained a piece of wood, some unidentified fruit tissue, and meat; this was probably an early dry-season meal.

During the Palo Blanco phase, therefore, it would appear that Coxcatlan Cave was occupied from the mid-wet to the mid-dry season.

Zone VI shows that pochote root was still the dom-

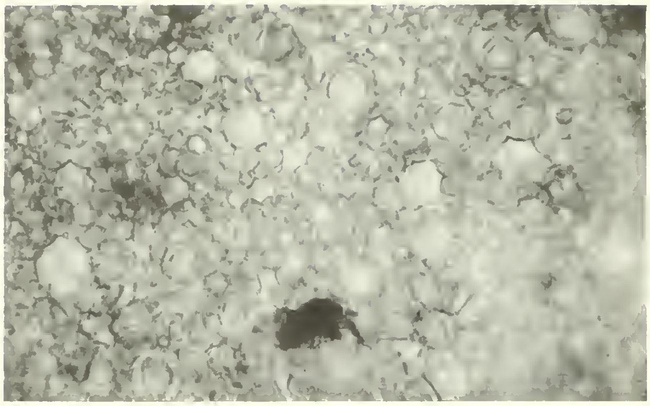


Fig. 180. *Cucurbita* mesocarp, showing the occasional grouping of cells in rosettes.

Fig. 181. *Cucurbita* testa has a characteristic wavy pattern.

inant plant material in the cave or wild diet of Palo Blanco times. Fragments of chili pepper occurred sparsely on five occasions, *Cucurbita* once, and maize not at all in the nineteen coprolites from the same square and level of Zone VI. If the individuals who used the cave had brought food from home, one or more of these cultigens should have shown up in quantity.* Furthermore, if they had come from home within the previous twenty-four hours or so, these cultigens would have shown up plentifully in the coprolites also. It is clear, therefore, that the individuals who had used Coxcatlan Cave had been away from home for forty-eight hours and were living off the land, using the same plants as their ancestors.

The chopped maguey or yucca buds showing the immature stamens in Cop. 94 of Zone V represent a delicacy still eaten in the Tehuacan Valley today. This is the only time such material has been found in the coprolites. Other plant materials eaten with it were beans, pineapple, and maguey tissue. Another coprolite (no. 46) with this latter combination of three plants appears in the Venta Salada phase. The presence of pineapple (identified by the characteristic appearance of seeds and bracts) is actually of great interest, as this seems to have been an imported fruit at that time—a true luxury item—there being no evidence of its cultivation in the valley.

Cop. 74 of the Palo Blanco phase contained two cultigens, with maize a co-dominant material and squash almost as common. The plants eaten along with them were cactus tissue and maguey.

In Zone IV the use of at least three different cacti at one meal (Cop. 96) is of interest. Although some cacti may have been cultivated at this time, it would appear that those eaten were probably wild, since the other plants involved undoubtedly are. Another Zone IV coprolite (no. 101) contained pochote and maguey tissues plus meat. This combination probably represents a hunting diet.

Pochote root, *Opuntia*, and maguey tissues appear still to have been roasted, and even charred on occasion, but not regularly so. On the other hand, there is no evidence of boiling.

At the present time, when chopped maguey or yucca buds are eaten, they are served with eggs, but no evidence of egg was detected in Cop. 94. Actually the bud material appeared slightly brown as if lightly roasted, but this color could be attributable to the retention of bile pigments by actively dividing tissue.

The presence in Zones IV to VI of coprolites from what are probably peasants tending fields throws some light on their dietary habits, since much of their food was roasted. The squash exocarp (Cop. 74) was very definitely roasted, as was the chili tissue; tissues of maguey, *Opuntia*, *Lemaireocereus*, and, of course, pochote all show evidence of roasting.

Of the twenty-one coprolites in Zone VI, sixteen contained meat. The type of meat in Cop. 36 is identified by the presence of mouse vertebrae. Bone was present in two other coprolites, but could not be identified. Four of the five coprolites from Zone V contained meat, the source of which was identifiable in two cases. Cop. 74 contained hairs of Audubon cottontail, as did Cop. 94. In Zone IV six of the eight coprolites contained meat. Of these, only Cop. 99 had hair and bone as well: analysis revealed plentiful hair of peccary, a few of Audubon cottontail, and a human hair.

* It may be assumed, however, that little recognizable evidence of maize would remain if corn were eaten in the form of tortillas, atole, or pozole.—ED.

To sum up Coxcatlan Cave during the Palo Blanco phase: of twenty-one human coprolites from Zone VI, nineteen were from the same square and level; twelve of these had pochote root tissue as the dominant material. Other dominant or co-dominant plants were setaria, maguey, black sapote, and cactus. The remaining two coprolites contained no seeds and no meat. Seasonal indicators pointed to both wet- and dry-season meals.

In Zone V five coprolites represented late wet-season, early dry-season, and dry-season meals. Another coprolite contained what is believed to be a city dweller's meal, including chopped lily buds and pineapple. Still another coprolite contained two cultigens, maize and squash, among remains of wild plants and probably represents a peasant meal eaten some thirty-six hours after leaving home. Both coprolites probably represent dry-season meals.

In Zone IV pochote root and cactus were the dominant plants, but the presence of a few setaria seeds indicated late wet-season or early dry-season meals. The presence of three kinds of cacti together in two coprolites suggests a party, perhaps hunters, living off the land in the dry season. Two further coprolites with maguey and pochote root as co-dominant materials have indicator materials that suggest they represent early dry-season meals.

Pochote root, *Opuntia*, and maguey tissues were roasted or even charred. There was no evidence of boiling.

The meat consumed has been identified by the hairs as peccary and Audubon cottontail.

Insects recovered whole or in part included sucking lice, fleas, ticks, filth flies, fruit flies, beetle larvae, ants, and pseudoscorpions. Some of the ants resemble honey pot ants and may have been consumed.

San Marcos Cave

Only seven of the eighteen coprolites recovered from Zone B of San Marcos Cave are of human origin. The principal plant materials of these seven proved to be maguey tissue, *Opuntia* tissue and seeds, perhaps tissue of other cacti, mesquite seeds and leaves, and various other seeds.

In six of the coprolites maguey was dominant. Three types of seeds in two of these (Cops. 6, 92), in addition to cactus tissue, suggest wet-season meals, as does the combination of maguey, cactus tissue and seeds, and meat in Cop. 12. The others (Cops. 88, 90, 91), containing only maguey tissue and meat, are almost certainly dry-season meals. Cop. 87 contained both *Opuntia* tissue and seeds, seeds of another cactus, and mesquite seeds, all of which would indicate a meal of the wet or early dry season.

Maguey, then, was the dominant food plant of which we have evidence; some form of cactus was second in importance. This combination is in agreement with the diet from this same cave in the Ajalpan phase. The exceptions to this are the wet-season meals consisting of various seeds.

With regard to food preparation, the maguey tissues in Cops. 6, 12, and 90 were definitely roasted and charred. There are indications that the cactus tissue was roasted, at least in Cop. 6. There was no indication that meat had been roasted.

Bones the size of those of a young rabbit occurred in Cop. 12. There was no hair by which the animal eaten could be identified. A few very small pieces of egg shell recovered from Cop. 6 were too small to be further identified.

Zone D contained no human coprolites, but Zone C contained two. *Lemaireocereus* was the dominant material in Cop. 61, which also contained a little meat. One piece of pochote root and only half a glume of setaria suggest that this coprolite may represent an early dry-season meal. Cop. 64 is a meat coprolite with disintegrating rabbit bones. The vegetal materials are chili fruit and seeds and part of a tree-legume seed. These items, if eaten fresh, would fix the meal as a late wet-season or early dry-season one.

Zone B contained five human coprolites, three of them from the same square and level. Maguey and meat were present in all five, along with seeds of two or more types. They probably represent late wet-season or early dry-season meals.

Zone A contained two human coprolites. Cop. 66 had roasted and charred *Lemaireocereus* tissue as the dom-

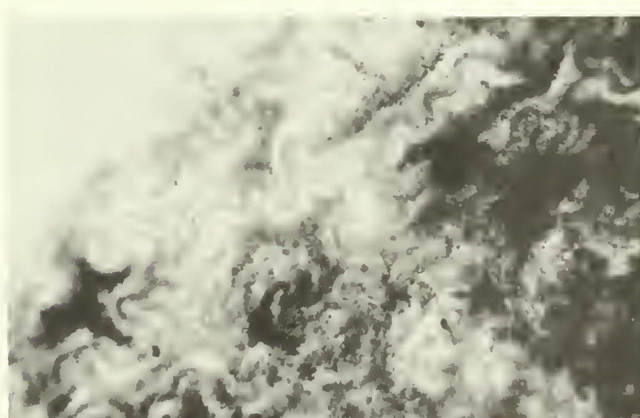


Fig. 182. *Capsicum* (chili pepper) testa shows an equally distinctive pattern.

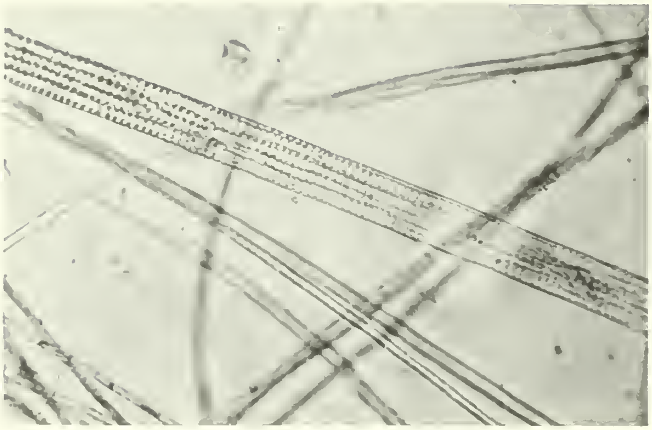


Fig. 183. Mature hair of Audubon cottontail.

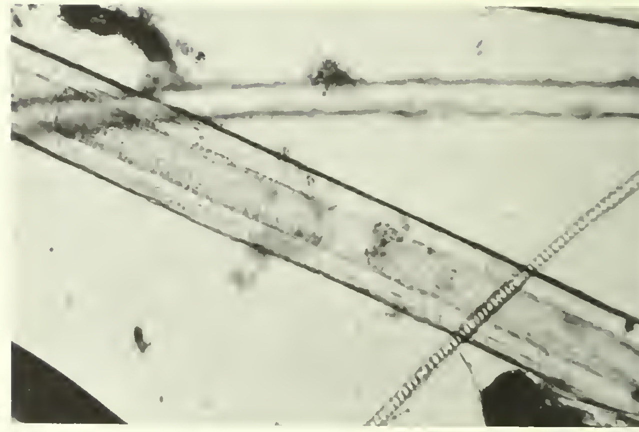


Fig. 184. Hair of ring-tailed cat.

inant material. Roasted and charred maguey tissues were also present. There was no meat. Cop. 67 contained maguey and *Opuntia* tissues as co-dominant materials, along with meat and what very likely is cassava. These coprolites probably represent dry-season meals.

The coprolites from Purron Cave show the same combination of maguey and meat supplemented by other materials that were seen in the coprolites from other caves of this and earlier phases. The dominance of *Lemaireocereus* in three coprolites emphasizes that local wild plants were used.

Charring or over-roasting of plant materials is definite in three coprolites only. *Lemaireocereus* tissue is charred in Cop. 54 (Zone E) and Cop. 66 (Zone A), maguey tissue in Cops. 66 and 67 of Zone A, and cassava tissue in Cop. 67. It has proved impossible to distinguish between the residual bile stain and light roasting of materials from the other coprolites.

Meat was present in all but one coprolite. It has been possible to identify hairs of Audubon and Mexican cottontail, ring-tailed cat, bobcat, peccary, and deer. A few human hairs were also present in Cop. 55.

In summary, in Zones E and C of Purron Cave, there were two coprolites with *Lemaireocereus* as dominant material (Cops. 54 and 61) and another two with meat as the dominant material. In Zone B there were five coprolites with maguey, cactus, and meat as dominant or co-dominant materials, *Lemaireocereus* being present in two of them. In Zone A there was roasted *Lemaireocereus* and roasted maguey in one coprolite, and roasted maguey, roasted *Opuntia*, and roasted cassava in another. Thus our evidence suggests that *Lemaireocereus* and maguey were the principal plants used in this cave. Seeds and other indicator plants seem to point to the late wet season or early dry season and the dry season as the most likely times for these meals.

El Riego Cave—East Niche

Ten coprolites, of which seven were of human origin, were recovered from the Palo Blanco phase of the East Niche of El Riego Cave. The human coprolites all came from Zone D. The principal plant materials of these were maguey and cactus tissues and various seeds.

Maguey tissue was present in five of the human coprolites and was dominant in four of them (Table 10). Most of the other plant materials were in the form of seeds, making it evident that all seven coprolites represent wet-season meals.

These coprolites contained, in fact, a number of seeds which had not been seen before. There were composite seeds which are not those of sunflower and solanaceous seeds that are not chili but could be *Physalis*. There were two different types of cactus seeds in Cop. 49 that are neither *Opuntia*, *Lemaireocereus*, nor jiotilla (*Escontria*). Cop. 49 also contained loments and tissue remains of mesquite pods.

Cops. 53 and 86 contained maguey tissue that was definitely charred, as was the cactus tissue in Cop. 50. However, there were no signs that any of the seeds had been subjected to roasting.

Meat had formed part of six of the seven meals represented in Zone D. It was the co-dominant material in Cops. 50 and 53. The meat in Cop. 50 was accompanied by a number of hairs and the bones and teeth of what seem to be mouse. The hairs were mainly those of Audubon and Mexican cottontail and bobcat. A few human hairs were also present in Cops. 50 and 51.

Adult beetles occurred in quantity in Cop. 45 of Zone D. They were broken up sufficiently so that it is certain they were eaten. In fact, they formed the co-dominant material with maguey tissue. *Sylvilagus* (cottontail) hair was also present. The shape and size

of the coprolite and the color of the trisodium phosphate in which it was soaked all point to a human donor for this coprolite.

Other insects that could be identified in human coprolites included a flea from Cop. 51 and the remains of beetles from Cop. 52.

In the East Niche of El Riego Cave during the Palo Blanco phase maguey was the dominant material in the human coprolites. The presence of several types of seeds indicates wet-season meals. Some of these seeds had not been found in earlier cultures. Meat sources were chiefly Mexican and Audubon cottontails and even bobcat.

Summary

According to the coprolites, meat sources in the Palo Blanco phase—as, of course, part of a cave diet, not a city diet—were mainly small animals, the kind that could be trapped. However, deer hair has been identified, so that some hunting was still practiced. At least two coprolites (Cops. 74 and 94) apparently represented a city diet.

At some stage of their cultural development, the Tehuacan Valley inhabitants must have learned to remove the developing buds from maguey plants, in order to hold the accumulated food in the crown of the plant and lengthen the season during which the leaves could be eaten. As we have pointed out, we believe that maguey was probably a cultivated as well as a wild plant in the Tehuacan Valley. The flower buds may have been yucca or squash, however. The pineapple eaten with the buds was almost certainly brought from a distance and represented an even greater luxury.

Leaves and stems of maguey and *Opuntia* and root of pochote were still eaten roasted. Squash and chili had been roasted as well. Setaria also showed signs of roasting. At this period, however, the grains and glumes were shattered. Preliminary observations indicate that this must have been done with a rolling motion, implying the use of grinding implements resembling the modern *mano* and *metate*. This is in contrast to the preparation of setaria in El Riego times, when a stirring or pounding motion fractured the grains in a manner suggesting the use of mortar and pestle.

Venta Salada Phase

Coxcatlan Cave and the East Niche of El Riego Cave each has three occupation zones of the Venta Salada phase. Only fourteen of the eighty coprolites from these six zones were of human origin, making the sample inadequate for any but very general conclusions. Of the sixty-six animal coprolites, one came from Tecorral Cave and the others from Coxcatlan and El Riego caves.

Table 35. Contents of Venta Salada Phase Coprolites from Tc 50

Zone	Cop. no.	Setaria	Pochote	Maguey	Lemaireocereus	Other cactus	Beans (Phaseolus)	Meat
III	26				‡	†*		‡
	46			‡			‡	†
	84	‡	†					
	87	‡	†					
	86				‡	†		
II	22			‡		†	‡	†
	24				‡*			†
	80				‡			
I	77	†	†	‡				

†Present.
‡Dominant or co-dominant.
*Tissue and seeds.

Coxcatlan Cave

The principal plant materials in the human coprolites from Zones I-III of Coxcatlan Cave proved to be maguey tissue, setaria seeds, *Opuntia* tissue and seeds, *Lemaireocereus* tissue and seeds, and common beans.

The earliest of the three zones, Zone III, contained five coprolites of human origin. Cop. 26 represents a meat meal, with *Lemaireocereus* tissue and some cactus fruit as sub-dominant materials, plus spores and pollen grains. A few coyote hairs were present. This very likely represents a late dry-season or early wet-season meal. Cop. 46, on the other hand, contained the interesting combination of common beans, pineapple, and maguey tissue as co-dominant materials, and in addition a grass flower with stamens and pollen grains, and meat. Study of the hairs reveals kangaroo rat as the source of the meat. The flower with stamens would indicate a wet-season meal. The bean-pineapple-maguey combination was also seen in the Palo Blanco phase, in Cop. 94.

Cops. 84 and 86 both came from the same square and level in Zone III. Both are composed principally of setaria, with traces of a number of other materials, but no meat. They probably represent wet-season meals, though the grain could have been stored. *Lemaireocereus* stem tissue was the dominant material in Cop. 86, which lacked meat and is likely to represent a dry-season meal.

Zone II contained three human coprolites. Cop. 22, composed of the remains of beans, maguey, and a little *Opuntia* tissue, quite likely represents a dry-season meal. A single deer hair was present. Cop. 24 consisted of *Lemaireocereus* fruits and disintegrating bone and probably came from a late dry-season or early wet-season meal. Cop. 80 consisted of *Lemaireocereus* stem tissue exclusively and probably represents a dry-season meal.

Zone I contained a single human coprolite, Cop. 77. Maguey is the dominant material. There are traces of setaria seed and pochote root, probably from a previous meal, and no meat. This probably represents an early dry-season meal.

The most notable plant in the coprolites of these zones is the organ cactus, *Lemaireocereus*, eaten in three of the nine meals as stem tissue, and once (Cop. 24) as fruit tissue and seeds. *Lemaireocereus* occurred as the dominant plant in the Purron Cave coprolites of Palo Blanco times and seemed typical of the diet of that cave. Two other such coprolites appeared in the Santa Maria level of Coxcatlan Cave. The Venta Salada *Lemaireocereus* coprolites from Coxcatlan Cave are, therefore, not unusual. The almost complete absence of pochote root, which in other phases is a regular part of the diet, is noteworthy.

The two setaria coprolites in Zone III follow the pattern established thousands of years before, in late El Riego times. However, the pattern of bean, pineapple, and maguey tissue (Cop. 46) has been seen in the Palo Blanco phase and is a "city" meal in contrast to a "cave" meal. A meal of beans and maguey (Cop. 22), this time accompanied by *Opuntia*, is a combination also seen in the Palo Blanco phase.

Lemaireocereus remains, which occurred in four coprolites, displayed no evidence of having been roasted or charred. If they were roasted at all, they were roasted only lightly. This appears to be true of the material in all coprolites except Cop. 77 of Zone I, which contained maguey tissue that was definitely charred. In two coprolites, consisting of a combination of bean and maguey, there was no evidence that either food had been roasted.

Meat was present in only four of the nine coprolites. In Cop. 24 (Zone II) the disintegrating bone seems to have come from an animal larger than a rabbit. In Cop. 46 (Zone III) hairs were identified as those of kangaroo rat. This coprolite, as we have noted, is the second meal containing pineapple to be found among the Tehuacan coprolites.

Among the insect remains in the human coprolites, bee and wasp were identified in Cop. 26, suggesting the eating of honey comb. This coprolite consists principally of meat, but it also includes *Lemaireocereus* tissue and fruits. Cop. 46 contained beetle elytra (wing covers), legs, and other parts; the leg of a louse; and the remains of a dermestid beetle larva (parasite on animal remains). The coprolites without meat did not contain insect remains, with the exception of one which contained a few scraps of unidentifiable insect cuticle.

El Riego Cave—East Niche

The principal plant materials in the human coprolites from Zones A–C of the East Niche of El Riego Cave proved to be maguey tissue; chili fruits and seeds; cactus tissue, fruits, and seeds; common beans; and maize kernels.

Zone C contained a single human coprolite consisting mainly of unidentified seeds and maguey tissue. Beans and chili seeds were also present, but since both could be stored, are no longer useful as seasonal indicators. On the basis of the unidentified seeds, this was probably a late wet-season or early dry-season meal.

Zone B also contained a single coprolite (Cop. 73) in which maguey tissue, tissue and seeds of chili fruit, and meat were co-dominant. Beans and cactus seeds were also present. This probably represents a wet-season meal.

Zone A contained three coprolites. Cop. 60 was chiefly cactus tissue and fruit, including young seeds, with some maguey tissue and meat. Cop. 61 consisted mainly of maguey and meat, and Cop. 62 of maize and meat, including a small piece of cob. Cop. 60 represents a meal of the early dry or late wet season, and the others probably represent dry-season meals.

Points to be noted about the plants identified in these coprolites are the continued use of maguey tissue as a main constituent of the cave diet in all three zones, and the combination of beans and chili pepper, so frequent in the present-day diet. The chili pepper in Cop. 73 had been eaten whole. Cactus tissue and fruits were also still being used. Neither the maguey nor the cactus tissues showed evidence of roasting.

A number of animals served as sources of meat. The hairs in Cop. 73 reveal that bobcat had been eaten, plus a very little coyote and harvest mouse; meat was the co-dominant material in this coprolite. In Cop. 60 the meat, identified by hairs, consisted of quite a lot of Mexican cottontail and bobcat, as well as a little kangaroo rat. There were no bones. The hairs in Cop. 61 show that a good deal of kangaroo rat and Audubon cottontail had been consumed. Cop. 62 contained bone chips, and the hairs indicated that a lot of Audubon

cottontail had been eaten. A young feather was found in Cop. 60.

Summary

Lemaireocereus, one of the organ cacti, formed an important part of the diet of the Venta Salada phase, more so than ever before in Coxcatlan Cave. It had appeared in the two coprolites from San Marcos Cave representing the Ajalpan phase and was used fairly extensively in Santa Maria and even Palo Blanco times. Like the pochote tree this cactus can only be described as a wild plant. The next most important plant in Coxcatlan Cave was maguey, which was frequently associated with beans. In the East Niche of El Riego Cave maguey was the principal plant food and was sometimes accompanied by beans and chili peppers. The combination of beans and chili is a pattern which has survived in the dietary habits to the present day.

Pochote root and, with one exception, setaria no longer appear to play a significant part in the Venta Salada diet, as they had done from late El Riego times right through the Palo Blanco period. Squash and maize have appeared mainly in animal coprolites, which may indicate that these two cultivars did not form a part of the human cave diet, but only of the city diet. Roasting of maguey and cactus still appeared to be practiced, though there is not so much evidence of it in this phase as in previous ones. Squash tissue had been roasted as well.

The meat eaten was mainly from animals that could be snared or trapped, such as mouse, cottontail, ringtailed cat, and bobcat. Small animals such as mice could only be identified by hairs, since bones were not usually preserved. This suggests some form of cooking other than roasting which would permit bones to be removed easily after cooking. In this phase remains of meat were absent from the coprolites more frequently than in any former phase, but it should be emphasized again that this was a cave diet, probably of peasants or slaves.

Tecorral and El Riego caves contained animal coprolites almost exclusively and probably were only intermittently used for human habitation. Coxcatlan Cave, on the other hand, was certainly inhabited by human beings during Venta Salada times.

Animal Coprolites

Of the coprolites from the Tehuacan caves, 121 were judged to be of animal origin on the basis of size, shape, smell, contents, and the color of the trisodium phosphate solution in which the individual coprolites were soaked. As pointed out earlier, each coprolite was soaked a minimum of 72 hours, and some colored the solution a pale straw yellow instead of a dark brownish or blackish shade. The pale coloration was frequently a determining factor in separating human from nonhuman feces.

Through hairs in the coprolites it was possible to identify the meat in the human coprolites and the more frequent victims of the various carnivores. There was little or no evidence, however, to identify the donors of the coprolites. Many were probably coyote feces, which physically resemble human coprolites, and some could perhaps be attributed to dogs, an animal introduced into the valley in Abejas times. Others may represent bobcats, skunks, raccoons, and opossums. Some specimens from the most recent levels turned out to date from post-Conquest times, being, quite obviously, burro droppings.

The only animal coprolite from the El Riego phase came from Zone XIX of Coxcatlan Cave. It contained a stone in the center, plus what appeared to be clay, and around that disintegrating bone. There were meat debris and spores of some kind, but no hairs and no other vegetal material.

The single animal coprolite from the Coxcatlan phase was from Zone F of San Marcos Cave. Roughly 40 percent by volume consisted of bone, which included vertebrae, ribs, and an atlas bone. Their size suggested mouse, but the few hairs in the coprolite were not identifiable. Meat debris and cartilage were also present. Some of the cartilage looked rather like insect chitin but actual insect chitin and larvae were also present. A little plant debris was present, but was not recognizable.

Two animal coprolites represent the Abejas phase. One was recovered from San Marcos Cave, Zone D, and consisted mainly of meat, with some bone but no hair. The bones suggest rabbit or something a little larger. The second coprolite came from Zone B of Abejas Cave. Recovered from it were patches of iguana skin with scales, as well as bones and teeth of a small animal. Study of the hairs present indicated that harvest mouse, Audubon cottontail, and traces of deer may have been eaten. Roasted plant material was present, but could not be identified. Beetle elytra (wing covers) were recovered, plus several insect abdomens that could not be identified.

The three animal coprolites from the Ajalpan phase were found in San Marcos Cave, Zone C. The plant remains in two were meager and unidentifiable. Cops. 1 and 4 contained hairs identified as those of Mexican and Audubon cottontails, along with rabbit-like bones. What appeared to be human hair was also present in

Cop. 4, but is probably a whisker, which closely resembles human hair. The third coprolite (no. 5) contained maguey tissue and some maize pericarp, along with meat debris and Audubon cottontail hairs, but no bones. This content could have come from a human meal, but the pale yellow color of the trisodium phosphate solution indicated an animal origin.

Most of the insect remains in the Ajalpan phase animal coprolites were unidentifiable scraps. In Cop. 5, however, were the remains of ants, probably accidentally ingested with grass and other plant material.

The Santa Maria phase is represented by eleven animal coprolites, of which nine were found in Zone VII of Coxcatlan Cave. Cop. 12 colored the trisodium phosphate a greenish brown, a color rarely seen, and had a strong ammonia smell. Among the meat debris in this coprolite was a complete knuckle held together by tendons (?), plus some other bones containing marrow. The vegetal material consisted of leaves and some charred material. The contents of Cop. 13 were mainly meat with some leaves and maguey debris. Cop. 23 also contained mainly meat, with grass and sedge remains among other leaves. There were chips from large bones and hair badly damaged by chewing—one of only two instances of such damage in the Tehuacan coprolites. The hairs were those of deer, coyote, and rock squirrel.

Animal Cops. 24–29 all contained meat as the dominant or co-dominant material, along with various kinds of fragmentary leaves, some of them grass or maize. The leaves were not fresh, but had already partially decayed on the ground. In some coprolites of this group were found maguey, cactus, what seems to be cassava, and even bean tissues of some type—materials which might indicate the donors were domesticated or semi-domesticated animals. The hairs in Cop. 25 reveal that substantial quantities of ring-tailed cat had been consumed. Cop. 26 also contained hairs of ring-tailed cat. Cop. 27 contained hairs of Audubon cottontail, as did Cop. 28. Cop. 29 contained hairs of Audubon cottontail, a few ring-tailed cat hairs, and one unidentified whisker.

The other two animal coprolites, Cops. 15 and 16, were obtained from Purron Cave. The most striking plants recovered from Cop. 15 were selaginella, a filamentous green alga, and the epidermis of a small *Tillandsia,* an epiphyte that often grows on the *Zizyphus pedunculatus* (cholulo) shrubs. This coprolite also contained disintegrating bone chips and must have come from a digestive system used to handling bone, rather than plant tissues. There were no hairs to suggest the possible origin of the meat and bone. Cop. 16 contained meat remains, maguey tissue, grass, and hairs of Mexican and Audubon cottontail and ring-tailed cat.

Thirty-seven coprolites represent the Palo Blanco phase. They usually contain meat debris and hair, and often bone and cartilage. The victims from the Palo Blanco animal coprolites, as identified by hairs, include deer, ring-tailed cat, raccoon, cottontail, and bobcat.

The vegetal material from these coprolites consisted largely of leaves, such as would have been (and still are) lying upon the valley floor—mesquite, acacia, cholulo, *Sideroxylon* (cosahuico), grass or reed fragments—and even maize leaves and slivers of wood. On occasion, maguey, chili pepper, and apparently cassava tissues were found.

Ten of the animal coprolites came from Zone VI of Coxcatlan Cave. The vegetal matter consisted of leaves of many kinds, sometimes a little maguey or cactus tissue, a few grass seeds, and even chili pepper tissue. The hairs in the coprolites represented mainly deer. The deer hairs in Cops. 38 and 39 were singed and those in Cop. 78 were well-charred. Some of these coprolites might be dog in origin.

Zone V contained five coprolites. One consisted merely of remains of meat with no bones or hairs by which to identify it. The others contained meat debris, leaves and twigs, scraps of possible cultigens, and hairs of ring-tailed cat and Audubon and Mexican cottontail. One also contained chips of bone, seemingly from a large animal.

Zone IV contained only two animal coprolites—one including jaws and teeth of a small animal, along with cactus tissue and seeds, and unrecognizable plant remains. Study of the hairs revealed that a fair amount of ring-tailed cat had been eaten, as well as the two cottontail species and bobcat. An odd whisker of unknown origin was also present. One of the Mexican laborers explained that this coprolite looked like coyote feces, which it probably was. The other coprolite contained no bones or hair, though it did contain cartilage. Plant remains were unrecognizable.

Several sucking lice (Mallophaga), a flea, and some ticks were found in these coprolites from Coxcatlan Cave. *Fannia* larvae, fruit fly larvae, several dermestid beetle larvae (probably of the genera *Anthrenus* and *Trogoderma*), as well as ants and the remains of pseudoscorpions appeared in both human and animal coprolites. These had obviously entered the coprolites when they were fresh.

Eleven animal coprolites came from Zone B of San Marcos Cave. Cops. 1–5 came from the same square and level. Besides meat debris, bone, cartilage, and hair, they contain leaves of mesquite, cholulo, and other plants and the pods of a tree legume. Deer hair was

present in all. Mexican cottontail and possibly raccoon hair appeared in Cops. 2 and 3, and ring-tailed cat hair in Cops. 1 and 5.

Cops. 7–11 from Zone B were meat coprolites. Hairs in Cops. 7 and 8 were identified as those of ring-tailed cat. Cop. 9 contained numerous hairs of Audubon and Mexican cottontail. Cop. 10 contained unidentified hair. Cop. 89 contained squash and maize remains along with meat debris, bone, and hairs of ring-tailed cat.

Six nonhuman coprolites came from four Palo Blanco zones of Purron Cave. One of them (Cop. 70) consisted only of cactus (*Escontria*) tissue and seeds. The rest contained meat and unidentifiable plant tissue. Mouse bones and hair of Mexican cottontail were found in Cop. 59, which also contained insect eggs, as yet unidentified. Audubon cottontail hairs appeared in Cop. 60. Ring-tailed cat hairs were present in Cop. 63. Mexican cottontail and ring-tailed cat hairs were identified in Cop. 69. Cop. 62 contained mouse teeth, meat which had been charred, and numerous hairs of Audubon cottontail.

Three animal coprolites came from El Riego Cave. Cop. 47 from Zone E contained a number of hairs identified as those of Audubon and Mexican cottontail. There were also remains of maize, beans, cassava, and unidentified fruit tissue, and possible maguey.

Zone D contained two animal coprolites. Cop. 46 was fossilized, but had apparently consisted mainly of meat. Cop. 48 contained the remains of common millipede, beetle, and hairs of deer and Audubon cottontail. Some cactus tissue, mesquite leaves, and bits of wood were the plant remains.

Of the Venta Salada phase animal coprolites, seven were recovered from Zone III of Coxcatlan Cave. Cop. 16, perhaps dog in origin, was a meat and squash coprolite. The meat was identified by hairs as deer and raccoon. Other plants included cactus, maize, and beans. Cop. 27 was an almost purely meat (deer and ring-tailed cat) coprolite. Cop. 82 contained maize silk as well as grains, a lizard bone, an unidentified mammal bone, and hairs of coyote and ring-tailed cat. Cop. 83 consisted mainly of meat, along with cactus and maguey tissues. The hairs present revealed that a good deal of ring-tailed cat and some Mexican cottontail had been eaten. Cop. 85 contained maize, *Opuntia* tissue, *Lemaireocereus* fruits, and no meat. Cop. 89 was a setaria and maize coprolite, with no meat. Cop. 88 contained millipede and adult beetle remains, a few Audubon cottontail hairs, a rib (snake?), maguey tissue, and some seeds.

In Zone II there were twenty-one animal coprolites, among which were several groups, each recovered from a single square and level of the zone. In one group (Cops. 1, 2, and 3) meat and maize were the co-dominant materials, with seeds, leaves, and other plant tissues present in smaller amounts. Maize silk was present in Cop. 2. The hairs in these three coprolites consisted of a good deal of ring-tailed cat and Mexican cottontail, as well as a little raccoon in Cop. 2 and bobcat in Cop. 3. Portions of adult beetles, ants, pseudoscorpions, nematodes, and beetle larvae were also recovered.

Some coprolites (nos. 15, 17, 19-27, 29-32, 42, and 45) were apparently burro droppings. They are not relevant to this study, since they date from post-Conquest times.

Other animal coprolites from Zone II included three probably of coyote origin, all of them with meat as the dominant material accompanied by cactus tissue, mesquite, or a leaf or two. The hairs in Cops. 17 and 25 indicate that a lot of deer and some raccoon had been eaten. Cop. 28 contained numerous deer and pocket gopher hairs and a few Mexican cottontail and ring-tailed cat hairs.

Cops. 41, 43, and 44 contained mainly meat and some grass or leaves. The hairs in Cops. 43 and 44 identified the sources of meat as deer and Audubon cottontail. The hairs in Cop. 41 were those of ring-tailed cat. Cop. 79 contained remains of Audubon cottontail and raccoon, together with grass flowers and *Tragacanthus* seeds. Cop. 81, probably turkey droppings, contained maguey, maize, squash, seeds of various kinds, and a little meat, which was probably from larvae.

Among the animal coprolites from Zone I is a group (Cops. 4–11 and 74) from the same square and level, all of which turned out to be of burro origin. Cops. 12, 14, 23, and 52 were also burro droppings and consequently are not relevant to this study.

Cop. 13, probably turkey droppings, contained maize, cactus, chili pepper, grass, the remains of a moss plant, and a little meat. The hairs in Cop. 76 indicated that a large amount of raccoon and a fair amount of ring-tailed cat had been eaten. A single coyote hair probably indicates the donor.

Because of the greater meat content, the insect population in the animal coprolites from the Venta Salada zones was high. Filth flies (*Fannia*), beetles (including dermestid larvae), ants, lice, mites, and spiders were frequently found. Pseudoscorpion and other arthropod remains also were present.

The majority of the coprolites from the Venta Salada zones of the East Niche of El Riego Cave were of animal origin. In Zone C there were nine, of which two,

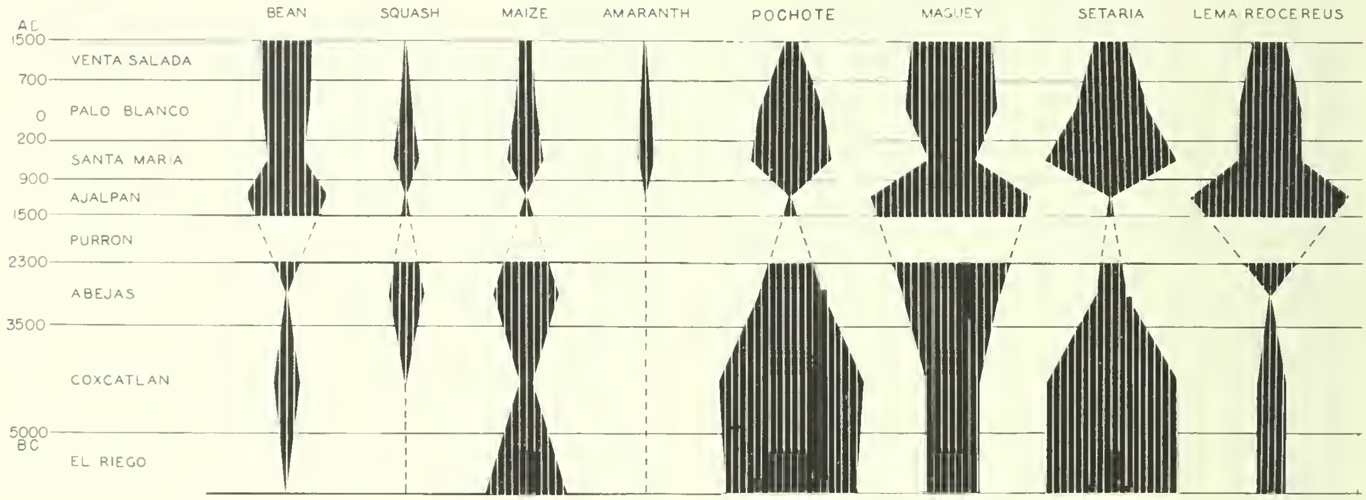


Fig. 185. Polygons showing the importance of various foods in the prehistoric diet. The number of coprolites in which a plant occurs is expressed as a percentage of the total human coprolites for each culture.

Cops. 67 and 68, were probably rabbit droppings. These contained cactus tissue and seeds, pollen grains, and unidentified tissue; there was no meat debris. Cop. 68 contained a few Audubon cottontail hairs probably indicating a member of this species as donor. Cops. 70–72 and 91–93 all contained meat and fair amounts of vegetal material including maize, chili pepper, maguey, setaria, and various seeds. These items, resembling a human diet, may indicate that the coprolites were dog in origin. Rabbit and mouse skull bones were present, and the hairs represent a variety of animals: Mexican and Audubon cottontail, kangaroo rat, bobcat, deer, and raccoon.

Zone B contained nine animal coprolites. Cops. 56–59 consist mainly of beetle and millipede remains suggesting a raccoon origin. Cop. 63, with the remains of adult and larval stages of beetles, may also be raccoon in origin. Cop. 64 is very similar.

Cop. 65 consists of cactus fruit and meat; the meat can be identified by the presence of rodent teeth and the hairs of bobcat, Mexican and Audubon cottontails, and kangaroo rat. Cop. 66 appears to have been two coprolites squeezed together; one of these seems to be burro in origin and the other contains adult and larval beetles. Cop. 69 had maguey and meat as co-dominant materials. The hairs present were identified as Mexican and Audubon cottontail. Cop. 90 represented a meal of meat, cactus tissue, and numerous seeds of different kinds. Among the hairs identified were a good many of Audubon cottontail and a fair number of ring-tailed cat.

The fact that most of the coprolites from the East Niche of El Riego Cave during the Venta Salada phase were of non-human origin suggests that the cave was too close to the cultivated fields and town or village homes to be much used by hunting parties or agricultural laborers.

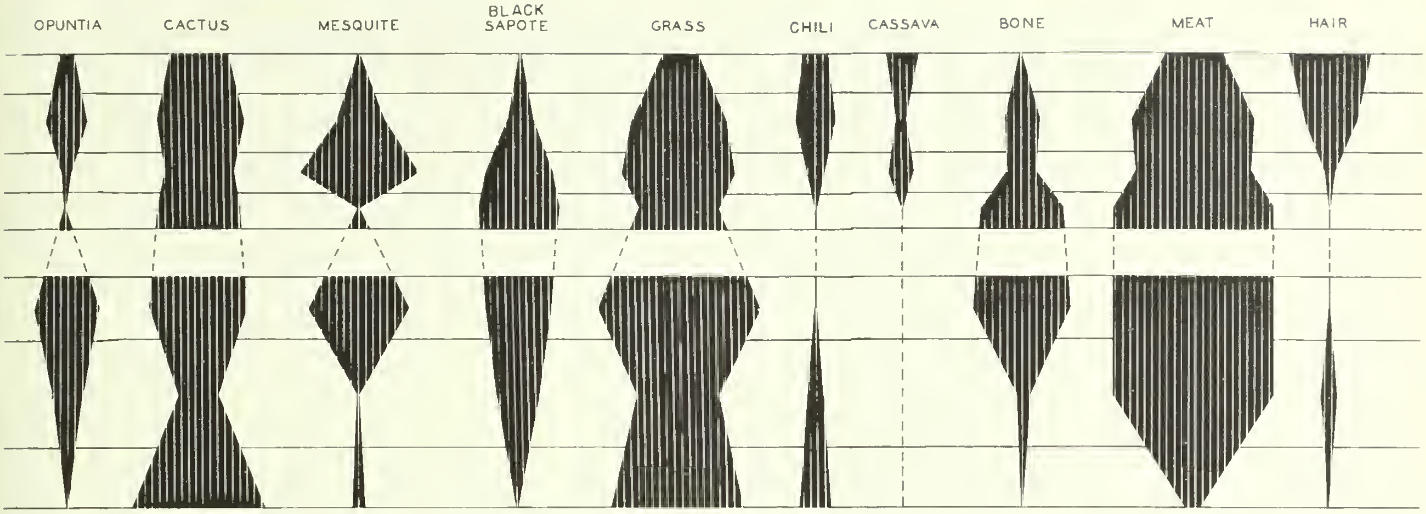
A single animal coprolite was recovered from the Venta Salada phase of Tecorral Cave. Cop. 75 was a meat coprolite containing skull and jaw remains of a small animal and hairs identified as those of kangaroo rat and bobcat. There were also a few fragments of insect cuticle and a trace of grass.

Conclusions

In the polygons (Fig. 185), the number of human coprolites in which a particular plant occurred is expressed as a percentage of the total of human coprolites for each culture. Since meat debris occurred in every human coprolite of the Coxcatlan phase, the figure for meat debris is 100 percent. If meat had occurred in only four of the twelve coprolites, the figure would have been 33 percent.

It must be borne in mind that the data assembled here come from several caves, each of which is represented by a slightly different dietary pattern. Most of the data for the Abejas and Ajalpan phases, for instance, comes from San Marcos Cave (Tc 254), while much of the rest of the data comes from Coxcatlan Cave (Tc 50). Thus, maguey tissue and meat emerge as the dominant materials in the two phases just mentioned, and setaria and pochote root, commonly the dominant plants in the diet of Coxcatlan Cave, are practically absent. No coprolites were recovered from the Purron phase.

On looking at the eighteen columns of Fig. 185 one first notes three main shapes: (1) the broad-headed



figures with pinched necks, (2) the fat ones, and (3) the thin ones. The broad-headed figures are those of pochote, setaria, and mesquite, which were absent from the two human coprolites representing the Ajalpan phase, but were back again as important food plants in the much larger sample from Santa Maria times. It was very noticeable that the dietary habits represented in late El Riego and early Coxcatlan coprolites and continuing into the Abejas phase disappeared from the two Ajalpan coprolites (which did not come from Coxcatlan Cave), only to reappear in the Santa Maria phase and continue into the Palo Blanco cave diet. Since the El Riego, Coxcatlan, and Abejas cultures are classed as the incipient agriculture phases of the Tehuacan sequence, this would mean that there was probably a shift in diet with the development of agriculture and urban communities. By the late Formative period represented by the Santa Maria phase, there must have been a very definite city diet based on maize, bean, and squash agriculture. However, the cave diet of former periods was adhered to by those occupying the caves, who utilized the wild plants growing nearby, just as their ancestors had done. This cave diet was then carried on into the Palo Blanco phase, and to a small extent into Venta Salada times.

The reference above to the main plants of an agricultural economy—maize, beans, and squash—draws attention to the fact that these are represented by intermediate to thin figures of Fig. 185, which should have blossomed forth into broad heads, but have not done so. There are traces of these plants in a few of the coprolites of the Palo Blanco and Venta Salada phases, which has led to the suggestion that they were deposited by travelers or hunters who had been eating a city diet not more than twenty-four hours earlier. The comparative absence of maize, beans, and squash leads to the supposition that travelers possibly, and hunters and workers almost certainly, did not carry with them much in the way of food when they left the towns and apparently depended on wild plants growing near the caves, and on the trapping of small mammals, to supply their immediate needs. This is my own interpretation, however, and differs from that set forth in the concluding chapter by MacNeish.

The thick figures in Fig. 185 represent meat, grass, and cactus, three categories that do not represent single species. Even so, as described earlier in the explanation of how data was assembled, *Opuntia* and *Lemaireocereus* have been separated from the other cacti; and *Zea* and *Setaria* from the other grasses.

The really thin figures are those of *Cucurbita*, *Amaranthus*, and hair. *Cucurbita*, the squashes, have been mentioned above as apparently being a constituent of the city diet but not usually of the cave diet, even in early times. Amaranth is another surprising absentee, or near absentee. Although practically absent from the coprolites, it was found on various floors of Coxcatlan Cave (see Table 26 in Chapter 12).

The presence of hair in human coprolites has been taken as an indication of the actual meat that was eaten. The vast majority of the hairs identified turned out to be from small mammals such as mice, cottontail rabbits, ring-tailed cats, and so forth, and occasionally from deer and peccary. Therefore, the hair graph figure, compared to the meat one, is indicative of skinning before eating, or perhaps before cooking, even with such small mammals as mice. The hairs that are found are probably owing to careless skinning, or may be "ambient hair" in general circulation around the area where the meat was prepared. Evidence of careless

skinning first appeared in the Santa Maria phase and increased through Palo Blanco and Venta Salada times. At the same time the amount of meat consumed in the cave diet decreased. These probably are coprolites from peasants or slaves.

Several other polygons do not immediately attract attention by their shape, and one of these is for bone. Roughly it increases and decreases as the meat profile does—in fact, it is a thinner image of the meat figure. This means, therefore, that the amount of bone swallowed, either accidentally or on purpose, has remained constant for some 7,000 years. Some of the bones were mouse bones, but always just an odd one or two, and therefore probably accidentally swallowed. Others are chips and slivers which by their size suggest animals somewhat larger than rabbit—in fact, deer, according to the hairs. Bone marrow was discovered in one or two coprolites, but the fragments are not susceptible to identification.

Another figure, with broad shoulders and a narrow neck, represents maguey or *Agave*. This plant was a staple which increased in use during the Ajalpan phase and continued to be used in fair quantity into Postclassic times. The plant had many uses, not just for the food value of its leaves, but also for the fiber derived from the leaves, and for an alcoholic drink derived from the sap. The leaves are in the best condition for eating late in the dry season, just before the plant flowers, when a great deal of food material has been stored in the plant in preparation for flowering. By cutting out the developing flower stalk, the food can be held in the leaves for a period of several weeks or even months. Probably the inhabitants of the Tehuacan caves discovered this at some stage in their agricultural development.

The cactus genera *Lemaireocereus* and *Opuntia* show different periods of use. The former, one of the organ cacti, at the present time occurs frequently around Coxcatlan Cave and less so around San Marcos Cave. *Opuntia*, the prickly pear cactus, also is more common around Coxcatlan Cave than around San Marcos Cave. Logically, therefore, *Lemaireocereus* and *Opuntia* should be eaten more frequently in Coxcatlan Cave. The polygons show that *Opuntia* was eaten to a greater extent in the earlier phases, but that *Lemaireocereus* was more popular from Ajalpan times on.

Two further figures should be mentioned, that of chili and that of cassava (*Manihot*). As can be seen, chili was used in El Riego times, the oldest record from the coprolites being seeds from Zone XIV. However, among the small seeds and vegetal remains on the floors of Coxcatlan Cave, chili fruit wall with epidermis was found from even earlier layers (see Chapter 12). The other figure, that of cassava (*Manihot*), first appeared in Santa Maria times (about 900–200 B.C.). The material matched stem tissue of *Manihot esculenta* Crantz supplied by the Montreal Botanical Garden. According to David Rogers (personal communication), formerly of the New York Botanical Garden, this is the oldest record for the introduction of cassava to Mesoamerica.

The remaining figure is the polygon representing *Diospyros digyna*, the black sapote. This tree was apparently not native to the valley and was introduced during the Coxcatlan phase (see Chapter 12). It requires irrigation in the Tehuacan climate, and as can be seen, its use increased steadily into Santa Maria times and then declined in Palo Blanco and Venta Salada times. This decline may have been due to a dietary change—perhaps the fruit became part of the city diet. The black sapote, however, was almost certainly cultivated near Purron Cave in Santa Maria and early Palo Blanco times, when a large dam supplied water for irrigation in the area.

The frequency polygons show clearly which plants formed the staples of the diet. In El Riego times, they were undoubtedly setaria and pochote root, with cacti, grasses, and some maguey. The chief difference in Coxcatlan times was an increased use of meat. In Abejas times beans and *Lemaireocereus* were absent from the diet, while several other plants showed definite increases: *Opuntia*, squash, maize, and mesquite. Coming to Ajalpan times maguey shows maximum use, also beans, *Lemaireocereus*, and black sapote. There is a definite fading away of most plants in the cave diet of Palo Blanco and Venta Salada times. This fading away applies even to maize and squash, though not to beans. As mentioned earlier, in these Classic and Postclassic times there was a peasant and probably a slave class that worked and harvested the fields, but apparently did not themselves eat the crops.

The absence of most plants from the animal coprolites of the incipient agriculture period of the Tehuacan sequence shows that the wild animals that used the caves were meat eaters. It is almost into Santa Maria times before plant material other than leaves could be found. The exception was cactus tissue. The leaves found in the meat coprolites were those that normally fall to the ground beneath xerophytic thorn scrub. Leaflets of mesquite (*Prosopis* sp.), or sometimes *Acacia* or *Mimosa*, along with leaves of cholulo (*Zizyphus pedunculatus*) and possibly grass were al-

most certain indication of an animal coprolite. Mesquite pods were, of course, eaten when they fell off the trees.

In the Santa Maria and more recent phases, the presence of bean, squash, maize, and other plants in the animal coprolites suggests more extensive cultivation of these crops, with consequent raids by such animals as raccoons, coyotes, and dogs. The bone, meat, and hair figures need no explanation, but it is noticeable that they narrow in the Palo Blanco and Venta Salada cultures, probably as a result of the increased amounts of vegetal material available.

Changes and Continuity in Diet

It should be clearly understood at the outset that in the Tehuacan sequence the earlier phases represent cave and rock-shelter dwellers, but later, when towns and cities had come into existence, the caves were probably inhabited intermittently, perhaps by peasants or slaves who planted and harvested the fields, or by hunters and trappers.

In the El Riego period, as far back as coprolites were recovered, a diet based on pochote root and setaria was in use and had probably been in use for some considerable time in Coxcatlan Cave. This combination of starchy root and grass seed, including wild maize, was accompanied by other wild plants such as maguey and cactus, and some meat. This dietary pattern continued through the Coxcatlan phase but disappeared in the Abejas phase, when pochote root was practically absent from the diet as reflected in the coprolites, perhaps because of the smallness of the sample from Coxcatlan Cave. No coprolites assignable to the Purron or Ajalpan phases were recovered from that cave, and the two coprolites from another cave do not show this diet combination either. In coprolites of the Santa Maria phase, obtained from Coxcatlan Cave again, the pochote root and setaria diet is represented as strongly as ever. It continued into Palo Blanco times, but practically disappeared in the Venta Salada phase.

The pochote root and setaria diet is accompanied in the Santa Maria level of Coxcatlan Cave by another dietary pattern of almost equal importance: *Lemaireocereus* and black sapote. These materials had been present in the Coxcatlan phase of Coxcatlan Cave, but as relatively insignificant items in the diet. However, *Lemaireocereus* was one of the principal plants in the coprolites from San Marcos Cave during the Ajalpan phase. When Coxcatlan Cave was again occupied in the Santa Maria phase, *Lemaireocereus* was much in evidence, while the old diet of pochote root and setaria continued in favor.

These two diets probably represent mainly wet-season or early dry-season meals. A dry-season meal consisting of maguey tissue and meat along with cactus or perhaps pochote root tissue, first appeared in the Coxcatlan phase coprolites and is most frequent in the Ajalpan phase. It seems not to have been used much beyond that period, possibly because it was replaced by other wild plant materials.

Perhaps one further diet should be mentioned here—the diet which I suspect is that of city dwellers. Two coprolites, one from the Palo Blanco phase (Cop. 94), and the other from the Venta Salada phase (Cop. 46), were almost identical, though only a few years or perhaps as many as a thousand may have separated them in time. They represent a diet of beans, maguey tissue, and pineapple fruit, supplemented with meat. Chopped flower buds and fair amounts of "beer" were additions to the diet represented by the Palo Blanco coprolite.

The oldest coprolites recovered from the Tehuacan sequence demonstrate that pochote root and setaria seed were dominant plant materials in the diet of the people of El Riego times. *Ceiba parvifolia* is a tree that bears pods containing edible seeds among a silky cotton, known locally as "pochote." This tree is native to the thorn-scrub-cactus vegetation of the east side of the valley. Tissues from the starchy root of this tree were common only in coprolites from Coxcatlan and Purron caves. No evidence from the coprolites shows ingestion of the black-coated seeds, which are the commonly eaten products of the tree today. However, on occasions the roots are eaten by hunting parties of the present day (C. Earle Smith, Jr., personal communication).

Setaria, however, may have been one of the early cultivars, since it may have been difficult to obtain wild in the quantities eaten in the El Riego phase. True, seeds of other grasses were collected at the same time—judging by leaf fragments, these included wild maize—but, nevertheless, the quantities of setaria eaten offer mute evidence that it may have been one of the earliest cultivated plants in the Tehuacan Valley. Setaria was also eaten in northern Mexico, as the coprolites of the Tamaulipas sequence demonstrate (Callen 1963). There, the oldest material containing setaria came from the lowest level of the Ocampo phase of Tmc 248, placing it at about 4000 B.C. Setaria was not obtained from the older Infiernillo phase of the Tamaulipas sequence. In the Tehuacan Valley, setaria was recovered from coprolites of Zone XVI (El Riego phase) of Cox-

catlan Cave, dating from before 5000 B.C. Among the small seeds from the floors of Coxcatlan Cave, setaria was obtained from every zone back to XXIII (before 6500 B.C.), showing that the seeds were consistently collected and brought to the cave.

Perhaps during the Coxcatlan phase, and probably not later than halfway through the incipient agriculture stage of the Tehuacan sequence—defined by MacNeish (1964*a*) as covering the El Riego, Coxcatlan, and Abejas phases—maguey and *Opuntia* may have become semidomesticates. When the maguey plant has flowered (which in some species climaxes about ten years of growth), the plant dies, but new shoots grow out from the base of the stem, so that the plant propagates itself vegetatively. Since they were using the plant for food, the inhabitants of the valley must have observed this and may have started to stick these shoots into the ground at places convenient to themselves. This might account for the increasing use made of the plant for food, not to mention its other uses.

Sections of the stem of *Opuntia* will readily root when broken off, and this too must have been observed by some of the valley's inhabitants. As a result, pieces of *Opuntia* stem were probably stuck into the ground at convenient spots. The increased occurrence of maguey and *Opuntia* in coprolites of the Abejas phase suggests this semidomestication.

The first remains of a maize kernel appeared in a Coxcatlan phase coprolite, and a whole squash seed appeared for the first time in an Abejas phase coprolite. Chewed seeds of squash were also recovered from one coprolite of the Abejas phase. This does not, of course, exclude the possibility that normally only the cotyledons were eaten and the seed coat discarded, though no such material could be identified. Chili, as recorded earlier in this summary, was known in El Riego times, as shown by seeds from the refuse of Coxcatlan Cave and also from the coprolites. Beans of the genus *Phaseolus*, which are known from the dried plant remains in the caves as early as the Coxcatlan phase, could be identified as the genus *Phaseolus* only in coprolites of the Palo Blanco and Venta Salada phases.

One plant which was brought into the valley apparently under cultivation is *Diospyros digyna*, the black sapote, which first appeared in coprolites of the Coxcatlan phase and remained popular into the Palo Blanco phase.

New plants that appear in coprolites after the incipient agriculture stage was concluded, include *Physalis*, *Manihot*, and *Amaranthus*. Amaranth does not really belong here, as there are records of its occurrence among the early plant remains from Coxcatlan Cave. Its first appearance in the coprolites, however, is from the Ajalpan phase.

Physalis, some members of which are known today as ground cherry or cape gooseberry, is known in the Tehuacan Valley as "tomate." The epidermis of some variety of these fruits appeared in the Santa Maria phase, and would on occasion form the sub-dominant material of a coprolite.

Another addition to the plant list in the Tehuacan Valley was *Manihot* or cassava. As mentioned earlier, the identification of this plant in a coprolite of the Santa Maria phase is the oldest record for this starchy plant in Mesoamerica.

Changes in Food Preparation

Examination of the setaria material from El Riego coprolites and then from coprolites of Santa Maria and subsequent levels revealed that the grains and their surrounding glumes, the hallmark of the tribe Paniceae of the grass family, had been broken or shattered differently in those two phases. As an experiment, setaria grains were broken down with a stone pestle in a stone mortar found in an El Riego level of Coxcatlan Cave. Antoinette Nelken of the Tehuacan Project carried out the experiment by using both a pounding and a stirring motion, each of which gave almost identical results. A comparison of these results with setaria from the El Riego coprolites suggests that either or both motions had been applied. Neither type of breaking agreed with setaria from Santa Maria and Palo Blanco coprolites. Miss Nelken then used a grinding stone or metate, such as can still be bought in the markets of the Tehuacan Valley, rolling a stone mano or "rolling pin" in the approved fashion. The resultant material matched the setaria recovered from the Santa Maria and Palo Blanco coprolites. Exactly when the change from one technique and set of tools to the other took place is not known, but on the basis of artifacts found, it could have been during the Abejas and Ajalpan periods. Since the setaria and other grass grains were pounded, they may have been used to make some kind of coarse dough, as there is evidence that the setaria was roasted. It seems unlikely that the grains were first pounded before being roasted dry. The seeds were definitely not "popped," like popcorn. Judging by the ground-stone implements recovered, by the time maize was domesticated the manner of grinding the grains and preparing the dough had been perfected by using setaria grains (MacNeish 1964*b*).

The pochote root appears generally to have been roasted, although the center of the root must have remained uncooked. The starch grains had not swollen

and were still contained within the plant cells. It would appear that when the roots were dug up they were thrown on the fire in order to burn off the soil and corky bark. This outer layer became charred, and some of it was swallowed along with the raw center. This practice appears to have continued from El Riego times up to the Spanish conquest.

Maguey tissue was frequently eaten raw, or at least there was little evidence of roasting or cooking. However, in about one quarter of the cases, there is evidence of roasting. *Opuntia* also was evidently eaten raw quite frequently, but occasionally there is definite evidence of roasting, and in fact, on at least two occasions, the stem piece had been roasted and then the contents scraped out and eaten, the charred epidermis evidently being discarded. This type of preparation was also used for other cacti, including *Lemaireocereus*, especially in the more recent phases of the sequence. In the later cultures roasting appears to have been more frequent than in the earlier incipient-agriculture period.

Squash was roasted, as pieces of epidermis and of mesocarp were found which were unmistakably browned by roasting. There is also a hint that *Physalis* fruits may have been subjected to some form of heat treatment, perhaps to burn off the outer husk that encloses the berry. There was no evidence that the cassava tissue had been roasted, in fact the starch grains appeared completely normal, just as with the pochote root.

Meat appears to have been roasted only occasionally, but evidence for this statement is scanty. Sometimes it merely rests on the presence of hairs which have become very dark brown.

Although bones were frequently absent from coprolites containing other indications that meat had been eaten, their absence cannot be taken as evidence that some form of cooking other than roasting had been used. The animal might have been roasted in its skin, and when finally cooked, the skin was broken open so that the meat and bones could be separated with relative ease. In animal coprolites bone, hair, and meat all occur together, and quite often pieces of skull or jaw or other bones were recovered. However, it is the hairs which enable the meat to be identified.

The animal hairs obtained from human coprolites are summarized in the following list, arranged according to the chronological order of Tehuacan sequence: El Riego phase, none; Coxcatlan phase, Audubon cottontail; Abejas, Ajalpan, and Santa Maria phases, none; Palo Blanco phase, Audubon cottontail, Mexican cottontail, ring-tailed cat, bobcat, collared peccary, and white-tailed deer; Venta Salada phase, Audubon and Mexican cottontails, kangaroo rat, bobcat, and white-tailed deer.

Human hair was also present in the human coprolites and seems to suggest the eating of scalp parasites. There is a remarkable absence of animal hairs of any kind in the human coprolites of the middle phases of the Tehuacan sequence. It is only in the two most recent, Palo Blanco and Venta Salada, that they occur in quantity. This would suggest care in skinning animals in the earlier periods, and a lack of it in later ones. Perhaps the peasants or slaves who were responsible for the coprolites in the caves did not prepare their meat as carefully as their ancestors had done.

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CHAPTER 15

A Summary of the Subsistence

Richard S. MacNeish

It is my fortune to draw what conclusions are possible from the excavated remains relating to the subsistence of the prehistoric inhabitants of the Tehuacan Valley. This chapter is in part a résumé of the data previously described by the botanists and zoologist and in part is an anthropologist's interpretation of these data. As the reader will notice, some of my conclusions and arrangements of the basic data—and Callen's materials are justifiably called basic—differ from those of my colleagues. These variations arise in no small part from the fact that my colleagues have studied the plants and animals in terms of botanical and zoological relationships and behavior, while I view these data from the standpoint of man's adjustment to and exploitation of these resources and his eventual manipulation of them for his own greatest benefit. Somewhat consciously, we have not attempted to settle the differences between our biological and anthropological interpretations because we feel that there is merit in both views and that their presentation gives this volume a broader outlook.

The Tehuacan Project was in large part concerned with reconstructing the ancient subsistence and tracing the development of agriculture in the Tehuacan Valley. We uncovered vast amounts of material that had considerable bearing upon these problems—almost 11,000 zoological specimens, about 100,000 plant remains, and over 100 human feces. Although most of these remains came from only five caves, they are of fundamental importance in reaching a solution of the problem of the development of agriculture in the Tehuacan Valley. They also relate directly to the larger problem of the origin and spread of plant cultivation and domestication in all of the New World.

We found wild corn (*Zea mays*), as well as twelve races of domesticated corn. Five species of beans were uncovered, including three varieties of common beans (*Phaseolus vulgaris*), two varieties of runner bean (*P. coccineus*), and a single variety each of tepary (*P. acutifolius*), lima (*P. lunatus*), and jack beans (*Canavalia* sp.). We found fragments of several kinds of cultivated squashes or pumpkins and of gourds—*Cucurbita mixta, C. moschata, C. pepo, Lagenaria siceraria, Crescentia cujete*, and *Apodanthera* sp. Numerous remains of fruits include remains of wild and domesticated avocado (*Persea americana*), black sapote (*Diospyros digyna*), white sapote (*Casimiroa edulis*), guava (*Psidium guajava*), ciruela (*Spondias mombin*), and in the feces a few tiny remains of what may possibly be pineapple. Fragments of both ground cherry or "tomate" *(Physalis* sp.) and peanuts (*Arachis hypogaea*) were dug up. Cotton (*Gossypium hirsutum*) boll fragments and cotton string or yarn were fairly frequent in our excavations. Bones of dogs (*Canis familiaris*) and turkeys (*Meleagris gallopavo*) were evidence of other kinds of domesticates. In the feces, fragments of cassava (*Manihot esculenta)* may be evidence of another cultigen, but definite proof that they are such is lacking.

Throughout almost the entire sequence, remains of the chili pepper (*Capsicum annuum*) and amaranth appeared. Certainly some of these specimens, particularly in later levels, are from domesticated plants, but the earlier remains are more fragmentary and one cannot assuredly say they were planted. Their almost continuous occurrence from Zones XIX and XVIII through the latest levels of Coxcatlan Cave—plus the knowledge that they were domesticated in later time—raises the possibility that they may have been domesticated from

El Riego time on. Admittedly, the evidence for cultivation at such an early period is far from overwhelming. However, the finding of a complete chili pod of definitely domesticated size in Zone XI (Coxcatlan phase), tends to support our belief that chili was domesticated in the previous phase.

C. Earle Smith in Chapter 12 has suggested the stimulating hypothesis that a number of other plants were cultivars, such as mesquite (*Prosopis juliflora*), maguey (*Agave* spp.), prickly pear (*Opuntia* spp.), *Leucaena esculenta, Bumelia latevirens,* the grass *Setaria*, and the fruits, ciruela (*Spondias mombin*), cosahuico (*Sideroxylon* sp.), coyol (*Acrocomia mexicana*), and chupandilla (*Cyrtocarpa procera*). I am least convinced by the evidence for the grass setaria, as there seems to be considerable indication that it was a wild collected plant. First of all, there is no proof of its being cultivated now or in the recent past. In the second place, its early increase among the remains before the advent of corn agriculture, followed by a rapid diminution in popularity, almost duplicates the trend of other seeds (grass, *Opuntia, Lemaireocereus, Acacia*) that were certainly collected from wild plants. Third, the seeds from later levels show no increase in size as do seeds of many cutivated plants. In addition, setaria grows most profusely near present water sources, such as the Rio Salado less than three miles from either Purron or Coxcatlan caves. However, during the time a large dam provided water near Purron Cave (Zones I-D), as well as during the period represented by Zones C[1] and B of San Marcos Cave, when that area was irrigated, setaria seed is almost totally absent from the deposits.

Also unconvincing to me is the evidence for the cultivation of mesquite. This species is, however, presently grown under cultivation in small amounts, although most of the mesquite eaten locally today comes from wild plants. The evidence against its being a cultivar is fairly strong. There is no increase in seed size in our excavated specimens either within the sequence or when the archaeological seeds are compared with modern wild specimens. Mesquite grows slightly better near water, and yet in the Purron Cave deposits contemporaneous with the dam it is noticeably absent. In fact, the only occurrence of mesquite in Purron Cave is in Zone B, after the dam had been destroyed. The case for the domestication of maguey, *Opuntia, Leucaena,* and *Bumelia* is much the same. Maguey and the prickly pears grow wild nearly everywhere in the valley at present and are easily collected. The archaeological specimens are no different from present-day wild ones. They might have been cultivated, since they were used in quantity and are easily propagated, but we do not have firm evidence that they were.

The *Bumelia* specimens occur spasmodically in late levels and are little different from modern specimens. This plant grows better under well-watered conditions, yet at Purron Cave, it does not appear until Zone A, well after the water held by the dam was gone. Thus I see little evidence for its cultivation and some evidence against it. *Leucaena esculenta*, although cultivated on a small scale today, is still collected from the wild. The archaeological specimens are identical to modern wild examples. Again, the archaeological specimens are not popular until late Formative times, and even then this tree, which grows best under well-watered conditions, is absent from most of the Purron levels when the dam was in use. Of the plants mentioned so far, this tree seems most likely to have been cultivated, but the evidence in hand does not prove that such did happen.

The evidence is slightly better for the palm fruit coyol and three other popular fruits of the valley, ciruela or hog plum, cosahuico, and chupandilla. All four of these plants flourish under well-watered conditions, and all show noticeable increases in popularity in Zones I-D of Purron Cave, when the dam was functioning. It must be added that there is not a one-to-one correlation, for specimens of coyol and ciruela do appear in Zones A-C, after the dam ceased functioning. These must have been gathered from some other watered area. It seems reasonable to assume that originally ciruela was either collected in the barranca forests or grown in the valley in watered areas. I suspect it was the latter from Formative times on, as pits of this plant occur in rather large amounts in most components. However, before this time it occurs so spasmodically that it was probably the former and cannot be considered a cultivated plant. Coyol seeds are present in some quantity in levels contemporaneous with the Purron dam but also appeared in Zones J and K before the dam and after it in Zone C and A again. They are so rare before the time of the dam that I assume they were brought down from the mountains or were harvested wild in the wetter parts of the valley.

Chupandilla, solely on the basis of large amounts of fruit used during the period the dam functioned, seems definitely to have been cultivated by Formative times. However, an observable increase in seed size among the unusually large sample in Zone XI of Tc 50 and the small sample from Zone F of Tc 254 suggests that cultivation may have begun as early as the Coxcatlan period.

Cosahuico also shows a slightly increased seed size

from the Formative period on and increases in frequency in the Formative and Classic levels of Purron Cave when the dam was in use. Probably it was under cultivation at that time. The rather large number of seeds in Zone XI of Coxcatlan Cave hint that it may have been first domesticated in the Coxcatlan phase; however, its relative infrequency in zones of the subsequent phase in Coxcatlan Cave, as well as its complete absence from Abejas or Coxcatlan zones of Purron and San Marcos caves argues against such an early beginning.

In summary, I see little or no evidence of the culivation of maguey, *Opuntia*, setaria, or mesquite; nor do I see any evidence that these were among the first domesticates which led to the domestication of such plants as corn, beans, and squash. Also, I believe the evidence indicates that coyol, cosahuico, and ciruela were possibly cultivated in Formative times, whereas chupandilla may have come under cultivation in late Coxcatlan times. The domestication of these plants seems to me to be the result of the earlier planting of such trees as avocado and the black and white sapotes rather than the converse. As for *Leucaena* and *Bumelia*, I see no real evidence of their cultivation at all. However, neither the evidence for the very early domestication of many of the plants suggested by Smith nor my opinion to the contrary is conclusive, and the case remains very much open.

Besides these ten disputed plants, however, we did find thousands of specimens of other domesticates that few can or will dispute. Further, these species begin to be cultivated early in the sequence and extend over a long time range. This material not only reveals the development of agriculture in the Tehuacan Valley, but when considered in conjunction with other archaeological plant sequences and botanical data, it throws much light upon the origin and dispersal of many New World domesticates. Let us consider, in the order in which they first appear among the plant remains, each of the domesticated plants in terms of these wider implications.

One of the earliest domesticated plants in the Tehuacan Valley was apparently the avocado (*Persea americana*). This fruit was present in Zone XXIV of Coxcatlan Cave, one of the earliest components with preservation. The pit from this level, as well as many of the pits from components of the El Riego phase, are obviously from wild trees. Some of the seeds from El Riego phase zones, however, are noticeably larger than others. Some of the seeds from Coxcatlan time on seem to fall within the range of size of modern cultivated avocado pits. The increased size, as well as the continuous appearance of the larger pits, I believe is evidence of early selection and planting. Therefore, avocados may have been planted as early as the El Riego phase, about 8000 years ago, and they were almost certainly under cultivation by 4000 B.C. They have continued being planted and improved until the present time in Tehuacan. The plant, moreover, is not now native to the Tehuacan Valley, nor can it grow under normal conditions in this arid region, nor is it likely to have grown in the valley even during slightly wetter periods. Therefore, it seems probable that our first domesticate was an import from wetter regions to the east or south. The only other archaeological specimens of avocado occur in Peru during Formative times from 750 to 100 B.C. Thus the avocado may have slowly spread from Mexico southward, but there also remains the possibility that it was redomesticated in the lowlands of South America near Peru. Only further archaeological and botanical studies can give us a definite answer.

Perhaps even earlier than avocado, and equally difficult to determine when it was first domesticated, is the chili pepper (*Capsicum annuum*). The complete specimen from Zone XI of Coxcatlan Cave is almost identical to modern domesticated specimens and differs from wild ones, so that the plant was certainly domesticated by the Coxcatlan phase. This fact, together with the relatively consistent (though not numerous) occurrence of chili remains back to Zone XIX and the fact that it is now an intruder into the valley, leads me to suspect that it was planted from early El Riego times. Of course, it is possible that during earlier wetter periods it may have grown in the valley. In Tamaulipas chili remains occur almost as early, in Infiernillo phase feces, while chili occurs in Huaca Prieta, Peru, from 3000 to 2000 B.C. Wild chili species are widespread in the New World from Mexico to at least as far south as Bolivia. For these reasons I suspect the plant was domesticated independently in a number of different areas.

The third plant that might have been domesticated very early is amaranth, but it grows wild in the Tehuacan Valley and we were unable to distinguish wild examples from domesticated ones among our specimens. Thus we have no clear evidence when this plant first came under cultivation, but its relatively continuous distribution throughout our sequence—starting in Zone XX of Coxcatlan Cave—makes me suspect that it was planted early. Archaeological examples of amaranth occur in the Southwest of the United States at about 4000 B.C. and in southeast Tamaulipas at about 2500 B.C. Whether these were domesticated at all or in-

dependently in a number of areas or whether amaranth spread from a single center cannot at present be determined.

The two segments of cotton from Zone XVI of Coxcatlan Cave, even though they resemble domesticated forms, I suspect were wild or intrusive because of the long temporal gap before we begin in the Ajalpan phase to have a continuous distribution of examples of this plant. The tiny fragment of corn leaf in the feces from the same zone was probably from a wild plant, since the few cobs from Zone XIII are predominately wild. The single *Cucurbita pepo* seed from Zone XIV is considered to be a wild form by Whitaker and Cutler, but the other two squash seeds from this zone are large enough to be cultivated and are tentatively identified as *C. mixta*. These early specimens, perhaps over 7000 years old, plus the fact that Tehuacan is near the center of diversity of mixta, indicate that mixta may have been first planted in or near the Tehuacan Valley. The relatively late appearance of mixta in Tamaulipas in A.D. 200 and in the Southwest about A.D. 1000 suggests that it had slowly spread from the Tehuacan region.

To summarize briefly, one can say that probably *Cucurbita mixta* came under cultivation near the end of the El Riego phase, while domesticated or semidomesticated chili and avocado may have been imported into the valley at slightly earlier dates. Amaranth may possibly have been planted about the same time, but examples of cotton, corn, and pumpkin from El Riego components are most likely wild. Also, the possibility that future investigation may uncover evidence supporting the case for the early cultivation of such plants as setaria, maguey, prickly pears, and mesquite, as suggested by C. E. Smith, must not be forgotten. Thus by the latter part of the El Riego phase there may have been the most incipient kind of incipient horticulture, with planted species composing a negligible part of the diet of the valley's occupants.

It is in the following Coxcatlan phase, beginning about 4900 B.C., that we have clear evidence among the plant remains of a number of definite domesticates. Avocado, chili, *Cucurbita mixta*, and chupandilla, which we have discussed previously, were very probably planted, and amaranth continued in use. Wild corn, of which we had only a doubtful trace previously, now becomes fairly prominent. This seemingly was of local use, but more important, a few early cultivated cobs among the remains suggest that the Coxcatlan people had been selecting seed for planting. Similar cobs from Bat Cave and southwest Tamaulipas of a later date, probably between 2500 and 1000 B.C., as well as examples of the early tripsacoid corn race that intrude back in Tehuacan in the following phase, suggest that the earliest cultivated maize spread out over a fairly large area from the Tehuacan environment.

A few rinds of bottle gourds (*Lagenaria siceraria*) occurred in this phase. Since no wild relatives grow in Tehuacan, it was probably planted first elsewhere. As yet neither botanical studies nor archaeological findings indicate where or when this species was first cultivated, but remains appear in Tamaulipas in the Infiernillo phase from 7000 to 5000 B.C., in the earliest levels with preservation in Peru about 3300 B.C., and in the southwestern United States from 4000 to 5000 years ago. Shortly after the first appearance of gourds, the squash *Cucurbita moschata* is represented by a few seeds. The lack of either archaeological or modern wild specimens in Tehuacan and its present distribution and diversity in the Central American tropics suggest that moschata was first planted in the latter area. It later spread northward, arriving in Tamaulipas by about 2000 B.C. and in the southwestern and eastern United States by the time of Christ. It also spread southward, arriving in Peru by about 1000 B.C.

Late in the Coxcatlan phase white and black sapotes (*Casimiroa edulis* and *Diospyros digyna*), both native to areas of heavy rainfall, spread into Tehuacan from a nearby wetter region. These fruits have not been found in other archaeological sequences. Also appearing in this phase is a single pod of the common bean (*Phaseolus vulgaris*). Wild species of this plant do not occur in Puebla, but grow along the west coast of Mexico in Guerrero, Oaxaca, and Chiapas, as well as in Guatemala. Common beans occur almost as early as those in Tehuacan in the Ocampo phase of Tamaulipas (5000 to 2200 B.C.). This distribution suggests that beans were first domesticated in west coast areas of Mesoamerica and early spread eastward to northeast Mexico and central Mexico. Later they may have spread northward, arriving in Hopewell at Kansas City about the time of Christ. They may also have spread southward down the west coast, arriving in Peru about 500 B.C.

All of these cultigens continued to be used in the Abejas phase in even greater amounts. The Tehuacaneros or their neighbors seem to have developed a new race of corn, pre-Chapalote–Nal-Tel from the early cultivated race, and this spread northward over the Mexican plateau to both Sonora and the Sierra Madre region of Tamaulipas and perhaps even into the Southwest of the United States. A few corn cobs with tripsacoid introgression also were found in the Abejas horizon. *Tripsacum*, a grass which will hybridize with corn, has not been found in Tehuacan. It is possible that the early cultivated race may have spread into an area of

tripsacum, become hybridized, and then spread back to Tehuacan.

Late in Abejas times (3000 to 2500 B.C.) three other domesticates appear. One of these is the canavalia bean, which also may occur in Peru as early as 2000 B.C., but sufficient study has not been undertaken to speak of its origin or dispersal. However, there is little doubt that it is an intruder in Tehuacan. A second import is the dog, which most certainly followed man across the Bering Strait from Asia and eventually southward to Mexico. In Tehuacan we have evidence that this animal was frequently eaten. The final import is tepary beans (*Phaseolus acutifolius*). The Tehuacan data suggest that the date of first domestication of this species must be pushed back in time and its place of origin moved southward down the Mexican coast.

The next two phases, Purron and Ajalpan, add little to the list of domesticates, even though the people of these early Formative periods were full-time agriculturists. One of the new cultigens is *Cucurbita pepo*, and considerable evidence indicates that it was first domesticated in Tamaulipas between 7000 and 5000 B.C. Evidently before it spread to Tehuacan, where it arrived about 1000 B.C., it had spread northward to the Southwest of the United States. It occurred there as early as 2500 to 1000 B.C., and some of the evidence from Mammoth Cave in Kentucky hints that it was in that area at the time, although more secure evidence from more recent excavations dates its occurrence somewhat later (Mangelsdorf *et al.* 1964).

It is also in the Ajalpan phase that we have string definitely made from cotton fiber. The early date (2500 B.C.) of cotton cloth in Huaca Prieta, Peru, together with botanical evidence, suggests this area is where cotton was first domesticated. It then spread northward (perhaps along with the concepts of the spindle whorl and the loom), arriving in Tamaulipas and Tehuacan between 1500 and 1000 B.C. and reaching the Southwest only slightly later (Martin *et al.* 1953).

A large number of cultigens were added to the Tehuacan sequence in the Santa Maria phase. These sudden additions may in part be owing to better preservation in the caves, but they also derive from new cultural contacts. Runner beans (*Phaseolus coccineus*) are present for the first time and date slightly earlier than they do in the Southwest. However, wild varieties are absent from both regions, although wild examples occur as early as 6000 B.C. in Tamaulipas. These data suggest that runner beans were domesticated somewhere north of Tehuacan, west of Tamaulipas, and south of the Southwest.

Rinds of the tree gourd (*Crescentia cujete*) were found in a late Santa Maria level, as well as in more recent ones. Examples have not been reported from other excavations. Although wild species are found in nearby wetter parts of Mexico, they have not been identified in Tehuacan. Little is known about the "tomate" (*Physalis* sp.), which was identified in feces in the same levels. Also, from a Santa Maria level tiny fragments of what appears to be *Manihot* were found in feces. If this is *Manihot esculenta,* then we have some ideas about its origin and distribution.

Studies of modern species, along with the finding of archaeological griddles, suggest that this plant was first domesticated in northern South America. It may have spread to Peru by 750 B.C. and perhaps to Tamaulipas by way of the Gulf Coast as early as 1000 B.C., and perhaps from there to Tehuacan by about 400 B.C. However, since Tamaulipas specimens have been classified as *Manihot dulcis* and since others say that *M. dulcis* and *M. esculenta* are one and the same, our tentative reconstruction is tentative indeed. One thing is certain: more investigation is needed on the origin and spread of this plant.

The other agricultural specimens from the Santa Maria horizon are all various races of maize. The unraveling of the origin and spread of each is equally complex, although all of them may have originally derived from the wild and early cultivated races of Tehuacan. Early Nal-Tel–Chapalote varieties are found earlier than those of Tehuacan both in Tamaulipas and Ocos, Guatemala, and their modern distribution is in the lowlands. I suspect our Tehuacan specimens came from another area, even though the Nal-Tel–Chapalote complex may have been derived from early cultivated corn that had spread from Tehuacan to the lowlands. The Nal-Tel–Chapalote race almost certainly derived from the earlier pre-Nal-Tel–Chapalote corn of Tehuacan. Since we have not found the transitional steps in Tehuacan, however, it probably originated in a nearby highland region of Mexico and then spread back to Tehuacan. The tripsacoid Nal-Tel–Chapalote hybrids may, however, have evolved in Tehuacan. The Zapalote Chico race, which seems to have been in part derived from Chapalote, may have originated outside the Tehuacan region and then diffused to it. The earliest South American corn specimens (1500 B.C.) seem to be related to the Chapalote or early Chapalote race that might have spread from Mexico to that region. The race of slender-pod popcorn found in Santa Maria levels, however, was a derivative of Chapalote or of other domesticated corns of South America that developed in that region and then spread back to Puebla.

The hybrid or tripsacoid slender popcorns may have developed in Tehuacan. Again more investigation is needed to explain the complex origins and spread of the Santa Maria corn races.

It may be in the Santa Maria phase, as well, that coyol, cosahuico, and ciruela came under cultivation in irrigated fields or in orchards near watered areas.

The Palo Blanco phase yielded several new domesticates. Three of these may have come from South America, where they occur in the wild state as well as in earlier archaeological contexts. One of these is the peanut (*Arachis hypogaea*), and the other is the guava (*Psidium guajava*). The third is less definite, because only very small fragments in feces have been tentatively identified as pineapple. Turkey bones also were uncovered in one Palo Blanco zone. Since the wild turkeys of northwest Mexico are closest genetically to the domesticated ones, and since turkey bones appear earlier in the Southwest of the United States (Martin *et al.* 1952) than in Tehuacan, we suspect that domesticated turkeys spread from the greater Southwest to Tehuacan. Also in the Palo Blanco horizon, we find one cob of Zapalote Grande corn, along with a number of cobs of the early Chapalote race.

Although a number of new varieties or races of older plants appear among remains of the Venta Salada phase, only one new species occurs. This is the sieva or small lima bean (*Phaseolus lunatus*), which is related to but probably was domesticated independently of the larger South American lima bean. Its occurrence in late times in Tehuacan parallels its appearance in Tamaulipas and the Southwest. Thus there is little archaeological evidence concerning its origin. Botanical studies, however, suggest it may have been domesticated from wild forms in Guatemala or southern Mexico and later spread to the three regions previously mentioned (which lack wild related species). Other plants introduced in the Venta Salada phase are two new varieties of common beans (11 and 13), another variety of runner bean (9), and four races of corn: Conico, Dent, Chalqueño, and Tepecintle. Exactly where the corn races first originated is difficult to tell from present archaeological and botanical information.

We have summarized the sequence of cultigens in the Tehuacan Valley and briefly pointed out their relevance to some of the problems of the origin and spread of New World plant and animal domestication. It should be obvious that considerable more research is needed to solve these problems, but at least we have made a start—I hope in the right direction. Even from our meager data one fact is apparent—there were multiple origins of New World agriculture. It should be noted too that there was no single unilinear development of agriculture in any hearth or hearths but a series of small developments of plant domestication in many regions that stimulated and contributed to the evolution of agriculture over a wide area.

Having dealt with some of the wider implications of the agricultural remains, let us now consider how the sequence of domesticates helped establish chronology in the Tehuacan Valley. As shall be noted in later volumes, the sequence of excavated zones and cultural phases suggested by the agricultural trends is in agreement with the sequence determined by artifact and pottery studies, as well as by the radiocarbon determinations.

A study of the sequence of domesticated plants and animals from the zones of Coxcatlan Cave (Tc 50) reveals trends of domesticates as well as ever-increasing amounts of agricultural produce. Comparisons of the components from other caves (Tc 254, Tc 255, Tc 35e, and Tc 272) containing large samples of preserved agricultural food stuffs with those from Tc 50 allows one to align the former in a relative chronological position in terms of domesticated food trends established from Tc 50. This, of course, by no means allows us to place all the components we uncovered, but at least it gives a chronology of the ones with food stuffs.

The earliest zones of the other caves seem to be Zones E and F of Tc 254, which have examples only of wild corn and chupandilla. These zones of San Marcos Cave seem to come after Tc 50, Zones XVI, XV, and XIV, which contain no corn, but before Zone XI, which has both wild and a few early cultivated corn cobs, as well as chupandilla remains. The presence of a chupandilla seed of fairly large dimensions in Zone F of Tc 254 hints that it may be more recent than Zones XII and XIII of Tc 50, which also have almost all wild corn and no large-sized chupandilla seeds. Zone D of Tc 254, with only a few more wild cobs than early cultivated ones, seems to come after Zone XI of Tc 50 but before Zone IX, which has more early cultivated cobs than wild ones. Further, like Zone X of Tc 50, it has a cob of early tripsacoid corn as well as remains of black sapote. Thus, it seems probable that Zone D of Tc 254 and Zone X of Tc 50 are roughly contemporaneous.

Some of the middle zones of Purron Cave (Tc 272) seem to fit into the Coxcatlan Cave trends next. Zones L, J, and H contain dog remains, suggesting that they come after Zone VIII of Tc 50 with similar remains. Also, Zones H, K^1, and I have larger proportions of early tripsacoid corn, while Zones G and H have cobs of the Nal-Tel–Chapalote complex. This again tends to place Zones K–G after Zone VIII of Tc 50, because the

latter lacks any tripsacoid Nal-Tel–Chapalote cobs. However, the presence of a number of other plants in Tc 50, Zone VII, would place Zones K–G before it. Zone C of Tc 254 also seems to fit into this general time period, since it has predominately early tripsacoid cobs, as well as a few Nal-Tel–Chapalote, wild, and early cultivated cobs. Its exact relationship to the Purron Cave zones is difficult to determine exactly, but it might fall between Zone J of Tc 272, which has more early tripsacoid than early cultivated cobs and none of the Nal-Tel–Chapalote complex, and Zone I, with only early tripsacoid and Nal-Tel–Chapalote cobs.

Zone F of Tc 272, with mainly Nal-Tel–Chapalote cobs, is very similar to Zones VII and VI of Tc 50, but it lacks the Zapalote Chico of Zone VI, hinting it was earlier. Zones A-E of Tc 272, with many slender popcorn cobs and slender popcorn hybrids, seem to come after Zone VI, which has only a very small proportion of them, but the relatively small amounts of late tripsacoid cobs and larger proportions of the Nal-Tel–Chapalote complex suggest they come before Zone V of Tc 50.

The presence of *Physalis* and tree gourd remains in Zones B and C[1] of Tc 254 suggest that they are probably later than Zones VI of Tc 50 and C of Tc 272. How much later is difficult to determine, but the presence in them of relatively large amounts of early tripsacoid and pre-Chapalote cobs suggests that they are not more recent than Zone IV of Tc 50, which lacks these races of corn.

The zones of the East Niche of El Riego Cave (Tc 35e) all seem to be more recent than the components previously mentioned, but they are difficult to place exactly. Zone E with a limited sample is the most difficult to relate to the zones of Tc 50. The occurrence of Variety 1 of common beans and the high proportion of late tripsacoid corn cobs suggests that it is after Zone IV or Zone V of Tc 50. Zone D of Tc 35e, which contains *Apodanthera* seeds, seems to come after Zone IV, and the larger amounts of Variety 1 of common beans tends to confirm this placement. Zone C, with a similar corn and bean picture, but with examples of Variety 9 of runner beans—present also in Tc 50, Zone III—suggests further that perhaps Zones C, D, and E of Tc 35e are after Zone VI of Tc 50 and before Zone III. This leaves Zones A and B of Tc 35e and Zones I and II of Tc 50 as roughly contemporaneous. The sample from Zone A of Tc 255 is so small it is difficult to place exactly, but it has a large number of slender popcorn cobs, as do the latest zones of Tc 35e and Tc 50.

Another means of aligning the components with preserved food stuffs is in terms of trends of estimated sustenance, that is, trends of foods used. These estimates are derived from calculations based upon the amounts of bone and plant remains uncovered in the excavated occupations and are supplemented by data derived from analysis of coprolites. Such estimates not only yield information that solve problems of chronology, but they also are reconstructions of the subsistence at a given time by a given group of people and reveal changes in the pattern through time.

The bulk estimates of food derived from all discarded plant and animal remains uncovered in major excavation are based upon calculations that are fraught with difficulties. We are here attempting to reconstruct from the fragments in the refuse the total amounts of the sustenance of each floor of the excavated sites in terms of liters of food represented. Ideally we would have liked to have this data transferred first into liters of usable food, then into food energy units such as proteins, carbohydrates, fats, and minerals. Unfortunately, since nutritional tools and nutritionists were unavailable for this task, we were not able to proceed beyond the first step. Perhaps someone will take our data and complete the task, thereby providing data for research into the problem of energy and culture.

Flannery, as explained in Chapter 8, was able to estimate the minimum number of whole animals used or eaten during each occupancy. For example, two right femurs of deer from a given floor meant that at least two deer had been eaten during this occupation. Since we estimate that a deer yielded about 20 liters of meat, the people of the floor had consumed at least 40 liters of deer meat.

Animals were classified into eight general groups on the basis of size and yield: those giving about 20 liters of meat, such as deer; 10 liters, such as puma; 5 liters, such as peccary; 2 liters, such as dog and coyote; 1.5 liters, such as raccoon and fox; 1.0 liters, such as rabbit, skunk, opossum, and turkey; 0.5 liters, such as cranes and other large birds, gophers, rats, and turtles; and finally small animals yielding less than 0.25 liters of meat, such as mice, snakes, lizards, and small birds.

The tools for measuring and estimating the vegetal foods were a liter can (courtesy of Pemex Oil Company) and a measuring cup marked in liquid ounces (33.8 ounces per liter). Our calculations were based upon fruits and vegetables bought in the Tehuacan market place, others collected in the fields, corn kernels representing the various races from storage bins of the Rockefeller Foundation, and actual archaeological specimens.

Market examples of *Cucurbita mixta*, *C. pepo*, *C. moschata*, and bottle gourds with rinds removed were

mashed up in our liter can and found to average about one liter of flesh apiece. Thus, we estimated an archaeological peduncle of one of these cucurbits as representing one liter of food. It might be added that a series of seeds and fragments of rind of the same species found in the same excavated square as the peduncle would be estimated as representing only one squash and one liter of food. However, seeds of different sizes or seeds from widely separated squares of a floor would be estimated as representing other specimens of squash. The flesh of avocados, guavas, and prickly pear and other cactus fruits averaged about 30 examples per smelly, sticky liter. Wild avocados were estimated as being about 60 fruits per liter. The flesh of 5 black sapotes equaled one liter, as did flesh of 8 white sapotes. With these multiple-seeded fruits, we were particularly careful to estimate the minimum number of whole specimens which our archaeological fragments represented by checking the spatial distribution as well as numbers of peduncles. About 400 peanuts (from the Hotel Peñafiel bar) filled our liter container. The fleshy interior scraped from ten *Opuntia* stems collected near Coxcatlan Cave made one juicy liter.

Also, the interior of 15 pochote pods from the same locale filled the liter container. It took the meat of about 250 *Condalia mexicana* seeds (and an afternoon of cracking seeds) to fill about a quarter of our liter can, so we calculated 1,000 of these seeds per liter. Our laboratory staff also spent an afternoon chewing pieces of pochote root and the basal ends of agave leaves before reaching the conclusion that about one-half the food and juice (not very tasty) was removed in chewing. Thus, one agave quid was equal to the same amount of food. Since we could squeeze about sixty wet quids into a liter can, we assumed that 60 quids had once represented one liter of food. The flesh from 60 chili peppers from the market equaled a liter, as did the flesh from 60 coyol, ciruela, cosahuico, or chupandilla seeds (the latter all supplied by Augustin Tejeda). Wild seeds were estimated at 200 fruits per liter. Various pods of various kinds of beans, mesquite, and guaje (*Leucaena* sp.) averaged about 20 seeds, and roughly 5,000 of these seeds filled a liter can.

The corn was harder to calculate. Mangelsdorf's studies indicate that wild corn averaged eight rows of almost seven kernels each, and using kernels of small green ears of about that size we estimated that about 10,000 kernels filled a liter can. Thus we could estimate the amount of food in kernels represented by each archaeological cob of wild corn. Fragmentary cobs were thought of as being a quarter of a whole cob. A cob of early cultivated or early backcross corn had about 120 kernels of a size to give 8000 kernels per liter. (We again used green kernels for this estimate.) Early tripsacoid cobs averaged about 160 kernels each, and about 4,000 kernels of this type (borrowed from the Rockefeller Foundation) filled our liter can. The Chapalote–Nal-Tel complex cobs each had about 310 kernels of a size that took about 2,700 Rockefeller kernels per liter. Later tripsacoid corn types had about 400 kernels per cob, and it took about 2,000 kernels of this type, also borrowed from the Rockefeller Foundation, to make a liter. Slender popcorn and later corn types had about 300 kernels per cob and were sufficiently large so that only 2,300 Rockefeller kernels were needed to fill our can.

Estimates of food plants such as amaranth, mesquite, yucca, acacia, setaria, and grass (most of which were seeds) were calculated by measuring in ounces the actual archaeological specimens from each component.

Obviously estimating the bulk food represented by our archaeological remains on the basis of these rough calculations involves some degree of error. However, the degree of error is consistent through time, and our calculations do reveal food or sustenance trends. The largest source of error is the lack of uniformity in the preservation of plant remains from each floor. We therefore attempted to estimate, for those floors with poor or spotty preservation, what the total amounts of the various plants present would have been if plants had been preserved over the whole floor. Some of the more recent floors—Zones I-IV of Tc 50, Zone C^1 of Tc 254, and Zones A-D of Tc 35e—did have preservation throughout their whole area, so no calculations were necessary.

However, in other floors this was not the case. In our calculations of total amounts for floors with incomplete preservation, we divided the number of square meters in which food stuffs were preserved into the number of square meters of the entire floor, and this gave us a figure we called the "preservation factor" or "PF." We then multiplied the number of preserved plants in a floor by the preservation factor to find out the number of plants the floor would have contained if plants had been preserved throughout its area. For example, plant fragments were preserved in only two of the ten square meters covered by Zone A of Tc 255. Thus the preservation factor was 5. The remains of each plant species recovered from this floor were multiplied by 5 to calculate the total amount of each plant the floor may once have held. These figures also are roughly equivalent to the nonperishable bone materials (and meat estimates derived from them) covering the whole ten square meters of Zone A. Thus we attempted to derive the

Table 36. Volume of Meat in Liters Estimated from Faunal Remains by Zone and Phase

	WILD GAME																							DOMESTIC ANIMALS							Totals by Phase and Zone		
	Yielding 20 liters of meat (deer)			Yielding 5 liters of meat (peccary, puma)			Yielding 2 liters of meat (coyote, ring-tailed cat, etc.)			Yielding 1.5 liters of meat (raccoon, fox, etc.)			Yielding 1.0 liters of meat (skunk, jackrabbit, iguana, etc.)			Yielding 0.5 liters of meat (large birds, turtle, etc.)			Yielding 0.25 liters of meat (mice, small birds, snakes, etc.)					Dog (2.0 liters of meat)			Turkey (1.0 liters of meat)						
	identified bones	estimated whole animals	total liters of meat	identified bones	estimated whole animals	total liters of meat	identified bones	estimated whole animals	total liters of meat	identified bones	estimated whole animals	total liters of meat	identified bones	estimated whole animals	total liters of meat	identified bones	estimated whole animals	total liters of meat	identified bones	estimated whole animals	total liters of meat	Total volume	Percent of diet	identified bones	estimated whole animals	liters of meat	identified bones	liters of meat	Total volume	Percent of diet	Meat from wild and domestic animals	Food from all sources	Percent of meat in diet
VENTA SALADA																															278.0	1,591.1	17
Tc 35e, A	10	1	20	2	1	5							36	10	10	11	5	2.5	5	1	0.25	37.8	25	3	1	2	7	2	4	3	41.8	154.3	
Tc 50, I	10	1	20										4	2	2	1	1	0.5	1	1	0.25	22.8	12	1	1	2	1	1	3	1	25.8	192.5	
Tc 50, II	6	2	40							3	1	1.5	12	4	4	2	2	1.0	1	1	0.25	46.8	15	3	2	4	4	1	5	1	51.8	319.1	
Tc 35e, B	11	2	40	9	2	10							17	3	3				1	1	0.25	53.3	38	1	1	2	5	1	3	1	56.3	142.6	
Tc 50, III	9	1	20				3	1	2	2	1	1.5	4	3	3	3	3	1.5				28.0	6								28.0	441.6	
Tc 255, A				1	1	5							5	4	4	9	3	1.5				10.5	21								10.5	49.9	
Tc 35e, C	15	2	40	4	1	5							26	9	9	6	4	2.0	6	3	0.75	56.8	19	24	2	4	15	3	7	3	63.8	291.1	
PALO BLANCO																															333.2	1,912.0	18
Tc 35e, D	16	2	40	8	1	5							41	10	10	4	2	1.0	1	1	0.25	56.3	49	23	2	4			4	3	60.3	114.6	
Tc 35e, E	8	1	20										7	3	3	4	1	0.5				23.5	37	4	1	2			2	3	25.5	63.7	
Tc 50, IV	25	2	40							1	1	1.5	7	2	2	4	3	1.5				45.0	15	5	2	4			4	1	49.0	298.8	
Tc 254, B	6	1	20	3	1	5							36	4	4	14	5	2.5	4	2	0.50	32.0	35	3	1	2			2	2	34.0	91.9	
Tc 254, C[1]										1	1	1.5	2	1	1							2.5	17								2.5	15.1	
Tc 50, V	10	2	40							3	1	1.5	9	3	3	1	1	0.5	1	1	0.25	45.3	12	1	1	2			2	1	47.3	364.0	
Tc 272, A													1	1	1							1.0	2								1.0	44.3	
Tc 272, B													3	1	1							1.0	2								1.0	41.0	
Tc 272, C	2	1	20							3	1	1.5	2	1	1	2	1	0.5	2	1	0.25	23.3	25								23.3	91.4	
Tc 272, D													5	1	1							1.0	1								1.0	109.7	
Tc 272, E	2	1	20							9	1	1.5	15	4	4							25.5	8								25.5	323.7	
Tc 50, VI	46	2	40	4	1	5				3	1	1.5	29	7	7	3	3	1.5	2	1	0.25	55.3	18	1	1	2	1	1	3	1	58.3	309.6	
Tc 272, F													3	2	2	1	1	0.5				2.5	5	3	1	2			2	5	4.5	44.2	
SANTA MARIA																															151.5	607.0	25
Tc 50, VII	66	4	80	2	1	5							25	9	9	1	1	0.5	4	2	0.50	95.0	32								95.0	297.5	
Tc 272, G													17	5	5							5.0	3								5.0	169.1	
Tc 272, H	4	1	20										26	6	6	3	2	1.0				27.0	40	7	1	2			2	3	29.0	68.2	
Tc 272, I	3	1	20										7	2	2	1	1	0.5				22.5	31								22.5	72.2	
AJALPAN																															24.0	70.2	27
Tc 254, C													1	1	1							1.0	3								1.0	30.3	
Tc 272, J	2	1	20										2	1	1							21.0	35	3	1	2			2	3	23.0	59.9	
ABEJAS																															202.8	678.6	30
Tc 50, VIII	21	2	40										7	2	2	1	1	0.5				42.5	26								42.5	163.1	
Tc 50, IX	44	3	60							1	1	1.5	13	2	2	1	1	0.5				64.0	34								64.0	185.3	
Tc 254, D													22	4	4	4	2	1.0	2	1	0.25	5.3	20								5.3	26.2	
Tc 50, X	60	4	80	2	1	5	1	1	2				6	2	2							89.0	29	1	1	2			2	1	91.0	304.0	
COXCATLAN																															334.6	975.2	34
Tc 50, XI	143	9	180	3	1	5							27	8	8	4	3	1.5				194.5	34								194.5	569.0	
Tc 254, E-F	1	1	20	1	1	5	1	1	2				27	4	4	9	5	2.5	7	1	0.25	33.8	48								33.8	70.3	
Tc 50, XII	39	3	60							2	1	1.5	8	3	3				1	1	0.25	64.8	33								64.8	196.8	
Tc 50, XIII	15	2	40										3	1	1	1	1	0.5				41.5	30								41.5	139.1	
EL RIEGO																															487.8	902.4	60
Tc 50, XIV	91	8	160										26	6	6	1	1	0.5	2	2	0.50	167.0	55								167.0	304.9	
Tc 50, XV	67	6	120	1	1	5				1	1	1.5	16	4	4							130.5	61								130.5	213.8	
Tc 50, XVI	100	9	180										24	10	10				1	1	0.25	190.3	50								190.3	383.7	

amount of food for each floor by using three sets of data: liters of meat estimated from minimum numbers of whole animals derived from a study of the bones, liters of plant food derived from a study of the actual plant remains and estimates of the bulk yield of modern plants, and a calculation of the amounts of each plant one would have found in a given floor if preservation had been constant over the whole area. Again let me state that the figures derived from these data are estimates, and there is probably a large margin of error in each calculation. However, the figures do reveal trends of subsistence, and the errors are constant through time. These figures are presented in Tables 36, 37, and 38.

The earliest floor for which we attempted to calculate the bulk sustenance was Zone XVI of Coxcatlan Cave. Below that level plant preservation was too poor to make estimates of the sustenance feasible, and even in Zone XVI the sample is barely adequate. In this zone we uncovered 125 bones. Flannery (Chapter 8) identified 100 of them as being from at least nine deer, representing 180 liters of meat. Twenty-four bones came from ten animals that would yield one liter of meat each, and one lizard bone might represent 0.25 liters of meat. Thus about 190.3 liters of meat must have been consumed by the occupants of this zone. Plants were preserved in only one square meter of this floor covering about 50 square meters, so our preservation factor was 50. Using this factor, we estimated that three larger avocado pits were equal to about 5 liters of food from a cultivated plant. That is, the three pits were multiplied by the PF of 50, and the resulting 150 pits were divided by 30, the number of avocados per liter, to give 5 liters of avocado flesh. The chili pepper was estimated as representing 1.66 liters of food from a cultivated plant. Thus food from cultivated plants, rounded to one decimal, was calculated as 6.7 liters. The estimated amounts of food from wild plants were much larger, as Table 37 demonstrates, representing a total of 185 liters of food. In terms of percentages the occupants of Zone XVI seem to have obtained 48 percent of their food from wild plants, 2 percent from domesticated plants, and 50 percent from meat.

The picture from Zone XV is similar, and again preservation was far from perfect. The bones indicate that about 130.5 liters of meat might have been consumed. Three fragments of chili pepper epidermis recovered by flotation from the dust of three widely separate squares were assumed to come from three different chilis. Since about two of 80 squares had preservation, the preservation factor was 40 and the number of chilis became 120, representing 4.4 liters of food. Five of 11 avocado pits were sufficiently large to suggest that they came from planted trees, and multiplied by the PF they represented about 6.6 liters of food. Remains of various wild plants, including sizable amounts of fine edible seeds and six pits of what were probably wild avocados from the mountains nearby, were estimated as representing 72.3 liters, or 34 percent of the total food. Meat accounted for 61 percent and food from cultivated plants about 3 percent of the total diet.

Zone XIV of Tc 50, the final El Riego phase occupation, had slightly better preservation (a factor of 20). The bones represented at least eighteen animals that might have yielded about 167 liters of meat or 55 percent of the total food for the zone. Two avocado pits and three chilis, along with two seeds of at least one cultivated squash plant (probably *Cucurbita mixta*) represented 22.6 liters of food or 7 percent of the total. Fine seeds again were a major item among the wild plants, but stems or leaves and quids were also fairly prominent. The wild food plants were estimated as being 115.3 liters, or 38 percent of the total food.

Combining the three meager floors of the late El Riego phase, even though the sample is not very large and our estimates may have a wide range of error, does give us a set of figures to start with. The data as a whole from the three floors reveal that 372.6 liters or 41 percent of the total food came from wild plants, 40.3 liters or 5 percent from cultivated plants, and 487.8 liters or 54 percent from meat.

A glance at Tables 36–38 shows that the preservation factor decreases as preservation improved in the floors assigned to the Coxcatlan phase. Quids and leaf or stem fragments begin to outnumber small edible seeds among the wild plant remains. New species of cultivated plants include corn, squash, beans, and black and white sapotes. The wild plant foods represented a total of 500.7 liters or 52 percent of all foods combined. Food from cultivated plants (including half the amount of chupandilla represented in Zone XI) totaled 139.9 liters or 14 percent. Meat decreased in importance, representing 334.6 liters of food or 34 percent of the total. The trends through the El Riego and Coxcatlan phases are similar, with both wild and cultivated foods increasing and meat diminishing.

Preservation was poor again in the earliest occupation of the Abejas phase, Zone X of Coxcatlan Cave, but improved to a factor of 5 in each of the remaining three zones. Zone X contained the remains of one dog, but the two liters of meat it represented would have been a negligible part of the diet. The major portion of the food in these levels still came from wild plants, including large amounts of pochote pods and roots, agave

quids, and *Opuntia* stems. Foods from wild plants were estimated as 331.3 liters or 49 percent of the total diet. Cultivated plants, including new species of beans, furnished an increasing amount of food, estimated at 144.5 liters or 21 percent of the total. Meat accounted for 202.8 liters or 30 percent of the food consumed.

Food remains representing the Purron phase were so meager that we did not estimate the food used. The Ajalpan phase had a slightly better sample, but it cannot be considered adequate. The only floors containing plant fragments were Zone J of Purron Cave and Zone C of San Marcos. The former had preservation in only one of its 50 square meters. The latter zone covered approximately four square meters, one of which had preservation. These two small summer occupations contained only 90.2 liters of food, of which 55 percent is from cultivated plants, 18 percent is from wild plants, and 27 percent represents meat. These proportions are probably somewhat distorted by the unrepresentative sample for this phase. The trends from the Abejas to the Santa Maria phase would suggest that the Purron phase, for which figures are lacking, derived about 35 percent of its diet from agriculture, perhaps 31 percent from meat, and about 34 percent from wild plants. If we had a larger sample for the Ajalpan phase, we would probably see the figures we listed above corrected to about 40 percent from agriculture, 31 percent from wild plants, and 29 percent from meat.

The sample improved for the Santa Maria phase, largely because of well-preserved materials in Zone VII of Tc 50 (with a preservation factor of 2). Remains from three earlier zones (G–I of Tc 272) averaged 73.2 liters of food from agricultural plants, or 71 percent of the total food for the three zones; 18.2 liters of meat from wild animals, or 18 percent; and 11.1 liters from wild plants, or 11 percent. The bones of one dog in Zone H represented 2 liters of food and less than one percent of the total food for the three zones.

The much more adequate sample in Zone VII of Tc 50 revealed that agricultural remains, predominately corn, represented 132.8 liters of food or 45 percent of the total diet, wild plants 69.7 liters or 23 percent, and meat 95 liters or 32 percent. Combining all the Santa Maria refuse material reveals wild plant remains representing about 17 percent, meat 25 percent, and domesticated plants 58 percent of the total food.

The Palo Blanco components, with the exception of Zones A–F of Purron Cave, had the best samples of food remains. When one combines the food estimates from all Palo Blanco components, foods from agricultural remains comprise 65 percent of the total, wild plant remains 17 percent, and meat 18 percent. Thus the trend that started in the Abejas phase, with agricultural produce rising sharply at the expense of both meat and wild plant products, continues into Palo Blanco times.

The trend toward increasing agricultural produce (75 percent) continued into the Venta Salada horizon, with wild plant foods (8 percent) decreasing much more rapidly than meat (17 percent). The most reliable estimates can be made for this phase because six of its seven components (Zones I–III of Tc 50 and Zones A–C of Tc 35e) had food stuffs preserved over the entire areas occupied, and even Zone A of Tc 255 had preservation over a fifth of its living surface.

In terms of over-all trends of sustenance, our rough estimates reveal that agricultural food increased throughout the Tehuacan sequence, with the late El Riego phase deriving from this source 5 percent of the total food represented; Coxcatlan, 14 percent; Abejas, 21 percent; Purron, a projected 35 percent; Ajalpan, between 40 and 55 percent; Santa Maria, 58 percent; Palo Blanco, 65 percent; and Venta Salada, 75 percent. Wild plant foods show a gradual increase through Coxcatlan times and then a gradual decrease through the rest of the sequence. Wild plants probably accounted for 30 percent of the diet in the Ajuereado phase, and our estimates show they represented 41 percent of the diet in the later El Riego phase. They increased to 52 percent in Coxcatlan times, and thereafter decreased over the remainder of the sequence, to a mere 8 percent in the Venta Salada phase. Meat diminishes throughout the sequence. We might say it represented nearly 70 percent of the Ajuereado people's diet, and our estimates for the El Riego phase show that it accounted for 54 percent of the diet. This percentage fell to 34 in Coxcatlan times, and thereafter diminished gradually, to a final 17 percent in the Venta Salada phase.

Obviously, one supplement to or check on the estimate of food trends from the bones and plant remains recovered from the refuse is the sustenance trends revealed by Callen's analysis of food particles in the feces. Determination of trends from this source, however, presents a number of difficulties. First of all, certain foods digest more readily than others, and particles may not be discernible in the fecal remains. Second, certain ways of preparing food, such as soaking corn kernels in lime before grinding them into a fine paste, make it difficult to discern the particles in the feces. Third, there is usually not an adequate sample of feces from any single zone. Fourth, it is difficult to quantify the various proportions of food represented in the feces. Finally, there is no fool-proof

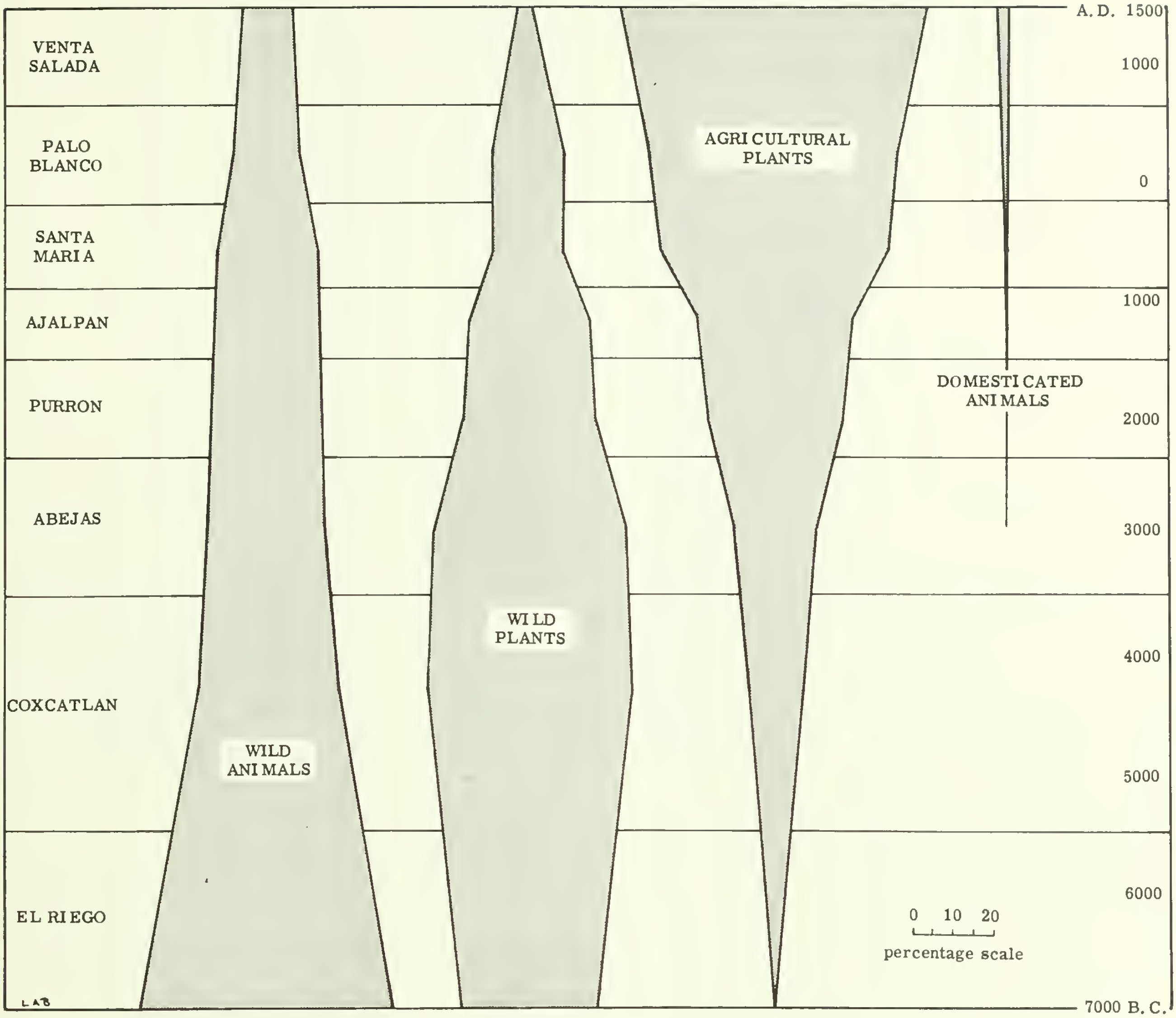

Fig. 186. Changing trends in the importance of the principal sources of food.

method of differentiating between human and nonhuman feces.

In terms of general categories, the trends of sustenance as revealed by the feces are very different from that derived from estimating plant and animal remains in the garbage. Meat, instead of beginning as the dominant food stuff and gradually decreasing, decreases in the coprolite sample from middle levels and then increases in later times. Further, the meat as revealed in the feces is always a small proportion of the total diet, never as large as the smallest percentage of meat as determined from the bones. This difference, I believe, can be accounted for by the fact that our sample of feces is less representative than the sample of bones, and more important, by the factor of digestion.

The trend of wild vegetal remains in the feces also bears small resemblance to the trends of wild plant remains from the refuse on the floors. In the feces, wild plants are always dominant, though they generally decrease throughout the sequenee, but the trends based on preserved plant remains show wild plants increasing from El Riego to Coxeatlan time and decreasing, at times sharply, thereafter. Part of this difference undoubtedly arises from the fact that many of the wild vegetal foods are not readily digestible and therefore are preserved in large amounts in the feces. However, when one looks at various proportions of the different

kinds of wild plants, estimates from the feces and from the refuse do bear some resemblance to each other. The dominant wild plant remains in both the garbage and feces in El Riego times are fine seeds (mainly setaria). In Coxcatlan and Abejas levels leaf or stem material increases, and in the later phases fruits show an increase.

However, the big difference in proportions shown by the two sources is in terms of the domesticated plants. Although particles of agricultural plants do increase in variety and slightly in proportion throughout the sequence in the coprolites, they never approach the sort of dominance in the later levels that they do in the estimates based on preserved plant remains among the refuse. This is almost entirely owing to the fact that little or no corn has been identified in the feces, whereas in the garbage estimates the tremendous increase in corn is the main reason agricultural produce increases. This lack of corn in the feces, I believe, can be accounted for by the following factors: corn kernels were soaked in lime to remove the tough pericarp, and from Abejas time onward, the soaked kernels were finely ground to make *nixtamal*, a highly digestible product which would be very difficult to distinguish in the feces. Also, some of the corn represented by cobs in the caves may have been exported to settlements and not eaten by the cave dwellers.

For the reasons I have stated above, I believe our study of the bulk food remains is a fairly reliable indicator of the foods actually used throughout our sequence, and a more accurate indicator than the food particles in the coprolites. The feces, however, do reveal certain foods not found in the refuse, and they give a clear indication of what wild plants were utilized, as well as how they and the other foods were used or prepared.

Of course, ancient food-preparation techniques are difficult to describe precisely or quantitatively. However, a consideration of the percentages of food used in each phase in light of the knowledge gained from study of the coprolites and from analysis of the artifacts and physical anthropology does indicate some trends and changes.

In the El Riego horizon 54 percent of the food was meat. The presence of a few scraped interiors of bones may indicate that marrow or bone stew was one way food was prepared, and carbon found with the bones may mean that a little of the meat was roasted. However, evidence from the feces suggests that most of the meat was eaten raw (or perhaps was steamed inside leaves). The wild plant remains composed 41 percent of the diet in the El Riego phase. Chupandilla, avocado, chili peppers, and various seeds from pods were probably eaten raw or with little preparation other than cutting or picking them from tree or bush. The pattern of wear exhibited by the teeth of El Riego skeletons gives evidence of the gnawing of raw leaves. Agave leaves, pochote roots, *Opuntia* stems, mesquite seeds, and grass seeds in feces seem to have been roasted. Such seeds as amaranth, *Lemaireocereus, Opuntia*, and setaria, seem to have been ground with a stirring or pounding motion (and were perhaps roasted). The presence of mullers, milling stones, mortars, and pestles in El Riego levels indicates that such a technique actually was employed.

The food remains and coprolites of the Coxcatlan phase show that some bones were scraped, some meat was eaten raw or steamed, and some meat was roasted. Fruits and vegetables that were probably eaten raw comprised about the same proportion of the diet as fleshy plant products such as agave and grass leaves, *Opuntia* stems, and pochote roots, which apparently were roasted before being eaten. Small seeds increase in number in this phase and perhaps represent over 10 percent of the food used. Some of these separated from the feces appear to have been milled, and mullers, milling stones, mortars, and pestles were found in increasing numbers. The presence of corn cobs and a few manos and metates may mean that a tiny amount of the food was finely ground.

In the Abejas phase more meat was eaten raw or steamed than roasted, and marrow or bone stew was becoming less popular. Raw vegetables and fruit probably represented about 40 percent of the diet and more than twice the share of roasted wild plants and cucurbits. Only a small proportion of the total food is represented by seeds of the type that could be milled. Increased amounts of corn cobs and metates and manos indicate that some of the food was finely ground. The presence of beans together with burned matter inside one stone bowl suggests that the technique of boiling food might have been known.

In the Ajalpan phase a fairly large number of pots with burned interiors or carbon adhering to the interiors are reliable evidence that some food was cooked by boiling. The large number of manos and metates, the type of wear on the human teeth, and the large proportion of corn cobs suggest that nearly a third of the food was finely ground. The lack of *comales* and the remains of food adhering to the inside of pots may indicate that the corn was eaten as gruel. Fruits, both wild and domesticated, comprised about a fifth of the diet and were probably eaten raw. Analysis of the coprolites show that cactus stems, agave leaves, and

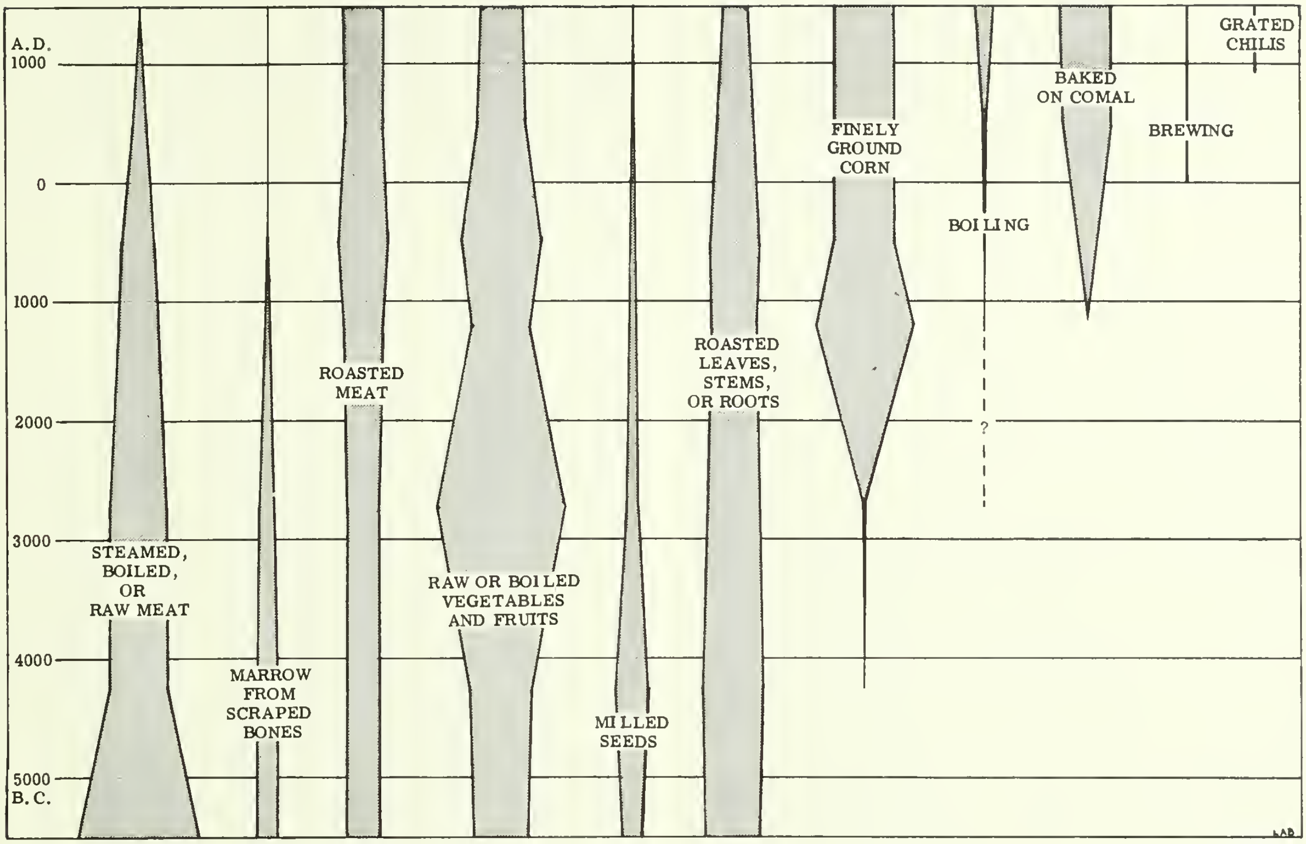

Fig. 187. Changing popularity of methods of preparing foods.

similar plant products were roasted. Seeds plus the milling stones and mullers suggest that a small fraction of the diet was milled. Probably half the meat was roasted and the other half was eaten raw or steamed. Only one bone was scraped.

In the Santa Maria phase meat was treated in about the same manner. About a quarter of the diet consisted of fruits and the like which were eaten raw. Roasted cucurbits, leaves, stems, and roots accounted for less than a fifth of the food, and a small fraction was still derived from seeds that were milled. A few pots and the presence of beans suggest some boiling of food. Corn made up over a quarter of the diet, and the presence of many manos and metates, as well as the pattern of wear on the human teeth of this phase, suggests that the kernels were finely ground. The presence of clay comales, on which tortillas traditionally are baked, suggests that about a fourth of the ground corn was grilled. The absence of corn in the coprolites representing this phase is probably attributable to the preparation, which made it highly digestible.

The trend of baking ground corn on comales continues in the Palo Blanco phase and accounts for about a third of the total food, but a large amount of corn was still only finely ground and accounts for about a fifth of the diet. A few seeds still were milled according to the mortars, not to the seeds themselves. Some leaves and stems were roasted and others were eaten raw. Most of the meat seems to have been roasted, but a little may have been boiled or eaten raw. The smell of one coprolite suggests brewing, a technique which may have become known in this phase.

In the Venta Salada phase the small proportion of meat used was probably roasted, although the presence of one mouse suggests boiling. Probably beans and some of the ground corn were also boiled. Fruits were still eaten raw, and leaves and stems were roasted. Large numbers of ceramic *molcajetes* undoubtedly indicate the grating of chili peppers, and a large number of comales suggests that perhaps two-thirds of the ground corn was baked as tortillas. Brewing was probably carried over from Palo Blanco times, as I know of no (Indian) culture that has given it up after the first drink.

The discussion of the food used, or the sustenance, and its preparation leads to an even more speculative

consideration of how the people got this food—the subsistence activities. Obviously our classification of the food into meat, wild plants, and cultivated plants suggests hunting and trapping, plant collecting, and agriculture—or more simply, food collection and food production. I believe, however, that a study of the plant and animal remains in conjunction with the associated artifacts—together with some general ethnographic knowledge—can given us concrete information about specific subsistence activities. We must fall back upon our bulk food data, the results of the food-getting endeavors. Ideally, a study of this sort ought to be based on the number of man hours needed to obtain the various kinds of food. I strongly suspect, for example, that the number of man hours needed to obtain a thousand liters of deer meat by hunting would be far greater than the number of hours needed to derive a thousand liters of edible corn from planting. Unfortunately, when this study was made, we had no means by which we could transfer the estimates of bulk food into the man hours necessary to obtain that amount of food. Perhaps such ethnographic information exists, but I do not know of it.

In spite of this limitation, let us consider how meat was obtained from El Riego to Venta Salada times. The bone materials show that the sources of meat can be divided into two classes—large animals, such as deer, puma, and peccary, which would probably be hunted; and small animals, such as various rodents, fox, skunk, turtle, lizard, and certain birds, which most likely would be trapped or collected. Further, the artifacts we found seem to fit these two general categories. The spear, atlatl, and arrow points and the broken shafts of atlatls and arrows must have been for hunting and killing animals, whereas the slip noose and fragments of snares and nets must have been connected with trapping. Thus at the outset we grouped our bones into those representing hunted animals and those representing trapped or collected beasts.

In terms of phases, late El Riego (Zones XVI, XV, XIV of Tc 50) had the remains of 24 large animals and 25 small ones; Coxcatlan, 18 large and 28 small animals; Abejas, 10 large and 17 small animals; Ajalpan, 1 large and 2 small ones; Santa Maria, 7 large and 28 small animals; Palo Blanco, 15 large and 69 small animals; and Venta Salada, 14 large and 63 small animals. Thus there is a definite trend from more animals' being hunted to more animals' being trapped and collected. Moreover, in terms of the amount of meat produced by the two techniques, hunting had decreased. Meat from big animals represented about 51 percent of the total diet in the late El Riego phase, 39 percent in the Coxcatlan phase, 27 percent in the Abejas phase, 22 percent in the Ajalpan phase, 20 percent in the Santa Maria phase, 13 percent in the Palo Blanco phase, and 12 percent in the Venta Salada phase. Trapping and collecting remained roughly the same, with El Riego, Coxcatlan, and Abejas each deriving about 3 percent of the total diet from this source, Ajalpan, 1 percent; Santa Maria, 6 percent; Palo Blanco, 3 percent; and Venta Salada, 2 percent. The tools of the latter trade were the snare with slip knot—and probably a quick movement of the hand or a well-aimed rock.

Study of the projectile points hinted that the hunting was probably of different kinds. In terms of function, projectile points seem to have been used in at least four ways. Small points like Harrell, Starr, Tula, and Teotihuacan, which in Tehuacan were associated with arrow shafts and in Tamaulipas were sometimes found attached to arrow shafts, are considered arrow points and indicate rapid-fire, bow-and-arrow shooting of game. Large points and points that are generally leaf-shaped, such as Lerma, Plainview, Agate Basin, and El Riego, are lance points and were probably used as spearing implements in ambush hunting.

Flannery has pointed out that the other projectile points could be divided into two groups, both used to tip atlatl darts: (1) Thin, sharp, weakly barbed points such as Pelona, Catan, Coxcatlan, Garyito, Zacatenco, and Matamoros, which would slash into and deeply penetrate an animal, and if they failed to hit a vital point, would cause the stricken animal to bleed so that it could be trailed until it dropped. (2) Large, relatively thick, barbed points which would remain imbedded in the prey and cause the animal to drop if enough were fired into it. The latter heavy dart points were probably used in stalking game, perhaps by a number of hunters, while the former may have been more often used by individuals.

The proportions of the various kinds of point types change through the levels in which we found animal bones indicating hunting. In the El Riego phase, with 51 percent of the total diet from meat of large animals, 21 percent of the points are lance points and 79 percent atlatl stalking points, suggesting that 11 percent of the meat came from ambushing or stalking with lances and that 40 percent came from stalking with darts. Thirty-nine percent of the food of the Coxcatlan phase was meat from hunted animals. Twelve percent of the points were lance tips, 59 percent were heavy dart points, and 29 percent were thin dart points, suggesting that 5 percent of the meat came from ambush hunting, 23 percent from stalking, and 11 percent from bleeding and trailing. The Abejas phase derived 27 percent of

Table 37. Volume of Food in Liters Estimated from Remains of Wild Plants by Zone and Phase

Zone / phase	Preservation factor (PF)	Yucca periculosa (izote): oz. of seed	oz. of seed x PF	estimated liters of food (33.8 oz. per l.)	Setaria cf. macrostachya and other grass seed: oz. of seed	oz. of seed x PF	estimated liters of food (33.8 oz. per l.)	Prosopis juliflora (mesquite): oz. of seed	oz. of seed x PF	estimated liters of food (33.8 oz. per l.)	Cactus seed Opuntia spp. Lemaireocereus hollianus Cephalocereus hoppenstedtii: oz. of seed	oz. of seed x PF	estimated liters of food (33.8 oz. per l.)
VENTA SALADA													
Tc 35e, A	0				2	2	*	12	12	0.4			
Tc 50, I	0				2	2	*	35	35	1.0			
Tc 50, II	0	33.8	33.8	1.0	2	2	*	5	5	0.1	1	1	*
Tc 35e, B	0							6	6	0.2			
Tc 50, III	0				2	2	*				1	1	*
Tc 255, A	5												
Tc 35e, C	0												
PALO BLANCO													
Tc 35e, D	0												
Tc 35e, E	3												
Tc 50, IV	0				0.5	0.5	*						
Tc 254, B	0	2	2	*				27	27	0.8			
Tc 254, C'	3				2	2	*						
Tc 50, V	3				3	9	0.3				1	3	*
Tc 272, A	2												
Tc 272, B	4												
Tc 272, C	4												
Tc 272, D	5												
Tc 272, E	5												
Tc 50, VI	0	445	445	13.2	19.2	19.2	5.7	213	213	6.3			
Tc 272, F	5												
SANTA MARIA													
Tc 50, VII	2				6.5	13	0.4	85	170	5.0			
Tc 272, G	20												
Tc 272, H	30												
Tc 272, I	50												
AJALPAN													
Tc 254, C	4	2	8	0.2				2	8	0.2			
Tc 272, J	50												
ABEJAS													
Tc 50, VIII	5				9.5	47.5	1.4	6	30	0.9	2	10	0.3
Tc 50, IX	5				6.6	33	1.0	64	320	9.5	1	5	0.1
Tc 254, D	5				1.0	5	0.1						
Tc 50, X	30										10	300	8.9
COXCATLAN													
Tc 50, XI	8				34.6	276.8	8.2	[illegible]	200	5.9	111	888	26.3
Tc 254, E-F	12												
Tc 50, XII	12	1	12	0.4	106.5	1,278	37.8	23	276	8.2	4	48	1.4
Tc 50, XIII	12	2	24	0.7	3.8	456	1.1	12	144	4.3	14	168	5.0
EL RIEGO													
Tc 50, XIV	20				[illegible]	[illegible]	[illegible]	29	580	17.2	10	200	5.9
Tc 50, XV	40				23.8	952	28.2	13	532	15.4	3.3	132	0.7
Tc 50, XVI	50	2	100	2.9	45.2	2,260	66.9	10	500	14.8	5	250	7.4

Zone / phase	Agave spp (maguey): oz. of seed	oz. of seed x PF	estimated liters of food (33.8 oz. per l.)	Acacia spp: oz. of seed	oz. of seed x PF	estimated liters of food (33.8 oz. per l.)	Persea americana (avocado): no. of seeds	no. of fruits x PF	estimated liters of food (60 fruits per l.)	Cyrtocarpa procera (chupandilla): no. of seeds	no. of fruits x PF	estimated liters of food (200 fruits per l.)
VENTA SALADA												
Tc 35e, A				23	23	0.7						
Tc 50, I												
Tc 50, II												
Tc 35e, B	1	1	*	11	11	0.3						
Tc 50, III												
Tc 255, A												
Tc 35e, C				16	16	0.5						
PALO BLANCO												
Tc 35e, D												
Tc 35e, E												
Tc 50, IV												
Tc 254, B												
Tc 254, C'												
Tc 50, V												
Tc 272, A	1	2	*									
Tc 272, B												
Tc 272, C												
Tc 272, D												
Tc 272, E												
Tc 50, VI												
Tc 272, F												
SANTA MARIA												
Tc 50, VII												
Tc 272, G												
Tc 272, H				4	120	3.6						
Tc 272, I				4	200	5.9						
AJALPAN												
Tc 254, C												
Tc 272, J												
ABEJAS												
Tc 50, VIII				*	–	–						
Tc 50, IX	1	5	0.1	*	–	–						
Tc 254, D												
Tc 50, X												
COXCATLAN												
Tc 50, XI				2	16	0.5				559	4,472	22.4
Tc 254, E-F												
Tc 50, XII				*	–	–				78	936	4.7
Tc 50, XIII										22	264	1.3
EL RIEGO												
Tc 50, XIV				1	20	0.6	3	60	1.0	1	20	0.1
Tc 50, XV							6	240	4.0	3	120	0.6
Tc 50, XVI							4	200	3.3	37	1,850	9.3

Zone / phase	Sideroxylon cf tempisque (cosahuico): no. of seeds	no. of fruits x PF	estimated liters of food (200 fruits per l.)	Spondias mombin (ciruela): no. of seeds	no. of fruits x PF	estimated liters of food (200 fruits per l.)	Opuntia spp (prickly pear): no. of fruit fragments	no. of fruits x PF	estimated liters of food (30 fruits per l.)	Other cactus spp.: Lemaireocereus Cephalocereus Escontria chiotilla: no. of fruit fragments	no. of fruits x PF	estimated liters of food (30 fruits per l.)
VENTA SALADA												
Tc 35e, A							5	5	0.2			
Tc 50, I							9	9	0.3			
Tc 50, II							19	19	0.6			
Tc 35e, B							7	7	0.2			
Tc 50, III							14	14	0.5			
Tc 255, A												
Tc 35e, C							14	14	0.5	3	3	0.1
PALO BLANCO												
Tc 35e, D							5	5	0.2	1	1	*
Tc 35e, E												
Tc 50, IV												
Tc 254, B							3	3	0.1	13	13	0.4
Tc 254, C'												
Tc 50, V							16	48	1.6	6	18	0.6
Tc 272, A							2	4	0.1			
Tc 272, B												
Tc 272, C												
Tc 272, D												
Tc 272, E							3	15	0.5			
Tc 50, VI							203	203	6.8	8	8	0.3
Tc 272, F												
SANTA MARIA												
Tc 50, VII							54	108	3.6	11	22	0.8
Tc 272, G												
Tc 272, H												
Tc 272, I	3	150	0.8									
AJALPAN												
Tc 254, C										2	8	0.3
Tc 272, J	1	50	0.3									
ABEJAS												
Tc 50, VIII	2	10	0.1	3	15	*	18	90	3.0			
Tc 50, IX	1	5	*				50	250	8.3	2	10	0.3
Tc 254, D												
Tc 50, X	3	90	0.5	2	60	0.3						
COXCATLAN												
Tc 50, XI	271	2,168	10.8	4	32	0.2	2	16	0.5	4	32	1.0
Tc 254, E-F												
Tc 50, XII	11	132	0.7				1	12	0.4	2	24	0.8
Tc 50, XIII	5	60	0.3	5	60	0.3				1	12	0.4
EL RIEGO												
Tc 50, XIV	2	40	0.2							1	20	0.7
Tc 50, XV				1	40	0.2						
Tc 50, XVI	5	250	1.3	200	10,000	50.0	1	50	1.7	3	150	5.0

Zone / phase	Malpighia spp: no. of specimens	no. of fruits x PF	estimated liters of food (30 fruits per l.)	Acrocomia mexicana (coyol): no. of seeds	no. of fruits x PF	estimated liters of food (60 fruits per l.)	Bumelia laetevirens: no. of seeds	no. of fruits x PF	estimated liters of food (200 fruits per l.)	Condalia mexicana: no. of seeds	no. of fruits x PF	estimated liters of food (1000 fruits per l.)
VENTA SALADA												
Tc 35e, A							2	2	*	1	1	*
Tc 50, I												
Tc 50, II										2	2	*
Tc 35e, B							13	13	0.1			
Tc 50, III							1	1	*	1	1	*
Tc 255, A												
Tc 35e, C												
PALO BLANCO												
Tc 35e, D												
Tc 35e, E												
Tc 50, IV												
Tc 254, B							6	6	*			
Tc 254, C'												
Tc 50, V										1	3	*
Tc 272, A												
Tc 272, B												
Tc 272, C												
Tc 272, D												
Tc 272, E										2	10	*
Tc 50, VI												
Tc 272, F												
SANTA MARIA												
Tc 50, VII							3	6	*	10	20	*
Tc 272, G												
Tc 272, H												
Tc 272, I												
AJALPAN												
Tc 254, C												
Tc 272, J				1	50	0.8						
ABEJAS												
Tc 50, VIII										83	415	0.4
Tc 50, IX				1	5	0.1				176	880	0.9
Tc 254, D												
Tc 50, X												
COXCATLAN												
Tc 50, XI				7	56	0.9				78	624	0.6
Tc 254, E-F												
Tc 50, XII	2	24	0.8	4	48	0.8				1,000	12,000	12.0
Tc 50, XIII	1	12	0.4							30	360	0.4
EL RIEGO												
Tc 50, XIV										2	40	*
Tc 50, XV												
Tc 50, XVI												

Zone / phase	Dioon edule: no. of seeds	fruits x PF	estimated liters of food (200 fruits per l.)	Quercus sp (oak): no. of acorns	acorns x PF	estimated liters of food (200 acorns per l.)	Prosopis juliflora (mesquite): no. of pods	pods x PF x 20 seeds per pod	estimated liters of food (5000 seeds per l.)	Leucaena esculenta (guaje): no. of pods	pods x PF x 20 seeds per pod	estimated liters of food (5000 seeds per l.)
VENTA SALADA												
Tc 35e, A							2	40	*	21	420	0.1
Tc 50, I										1	20	*
Tc 50, II	2	2	*							31	620	0.1
Tc 35e, B										4	80	*
Tc 50, III	2	2	*							17	340	0.1
Tc 255, A							8	800	0.2	6	600	0.1
Tc 35e, C										23	460	0.1
PALO BLANCO												
Tc 35e, D	1	1	*							1	20	*
Tc 35e, E												
Tc 50, IV										22	440	0.1
Tc 254, B										26	520	0.1
Tc 254, C'										24	480	0.1
Tc 50, V				1	3	*				3	180	*
Tc 272, A										7	280	0.1
Tc 272, B												
Tc 272, C										1	80	*
Tc 272, D												
Tc 272, E												
Tc 50, VI	4	4	*				16	320	0.1	4	80	*
Tc 272, F										3	300	0.1
SANTA MARIA												
Tc 50, VII	13	26	0.1				3	120	*	8	320	0.1
Tc 272, G												
Tc 272, H												
Tc 272, I												
AJALPAN												
Tc 254, C										21	1,680	0.3
Tc 272, J												
ABEJAS												
Tc 50, VIII										1	100	*
Tc 50, IX	1	5	*									
Tc 254, D										4	400	0.1
Tc 50, X	1	30	0.2									
COXCATLAN												
Tc 50, XI	7	56	0.3	2	16	0.1						
Tc 254, E-F												
Tc 50, XII	1	12	0.1									
Tc 50, XIII										1	240	*
EL RIEGO												
Tc 50, XIV							2	800	0.2			
Tc 50, XV												
Tc 50, XVI										4	4,000	0.8

Zone / phase	Ceiba parvifolia (pochote): no. of pods	pods x PF	estimated liters of food (15 pods per l.)	Acacia spp: no. of pods	pods x PF x 20 seeds per pod	estimated liters of food (5000 seeds per l.)	Prosopis quids: no. of quids	quids x PF	estimated liters of food (60 quids per l.)	Agave quids: no. of quids	quids x PF	estimated liters of food (60 quids per l.)
VENTA SALADA												
Tc 35e, A				18	360	0.1				242	242	4.0
Tc 50, I	9	9	0.6	2	40	*	2	2	*	224	224	3.7
Tc 50, II	125	125	8.3	9	180	*	46	46	0.8	1,268	1,268	21.1
Tc 35e, B	12	12	0.8	4	80	*	2	2	*	181	181	3.0
Tc 50, III	114	114	7.6	11	220	*	13	13	0.2	765	765	12.8
Tc 255, A				3	300	0.1				12	60	1.0
Tc 35e, C	8	8	0.5	8	160	*	12	12	0.2	712	712	11.9
PALO BLANCO												
Tc 35e, D	1	1	*	9	180	*	1	1	*	328	328	5.5
Tc 35e, E	2	6	0.4							32	96	1.6
Tc 50, IV	102	102	6.8	4	80	*	155	155	2.6	1,479	1,479	24.7
Tc 254, B	26	26	1.7	55	1,100	0.2	10	10	0.2	295	295	4.9
Tc 254, C'	11	11	0.7	3	60	*	57	57	1.0	123	123	2.1
Tc 50, V	42	126	8.4				37	111	1.9	679	2,037	34.0
Tc 272, A	24	48	3.2							16	32	0.5
Tc 272, B	8	32	2.1				6	24	0.4	6	24	0.4
Tc 272, C	3	12	0.8							30	120	2.0
Tc 272, D	3	15	1.0							201	1,005	16.8
Tc 272, E										709	3,545	59.1
Tc 50, VI	258	258	17.2	16	320	0.1				1,254	1,254	20.9
Tc 272, F	4	20	1.3							78	390	6.5
SANTA MARIA												
Tc 50, VII	165	330	22.0	3	120	*	91	182	3.0	486	972	16.2
Tc 272, G										42	840	14.0
Tc 272, H										4	120	2.0
Tc 272, I	1	50	3.3							1	50	0.8
AJALPAN												
Tc 254, C	2	8	0.5				3	12	0.2	28	112	1.9
Tc 272, J												
ABEJAS												
Tc 50, VIII	174	870	58.0	4	400	0.1				238	1,190	19.8
Tc 50, IX	113	565	37.7							62	310	5.2
Tc 254, D	5	25	1.7	5	500	0.1				161	805	13.4
Tc 50, X	10	300	20.0							65	1,950	32.3
COXCATLAN												
Tc 50, XI	177	1,416	94.4	1	160	*				342	2,736	45.6
Tc 254, E-F	1	12	0.8				1	12	0.2	160	1,920	32.0
Tc 50, XII	23	276	18.4	4	960	0.2				106	1,272	21.2
Tc 50, XIII	46	552	36.8							63	756	12.6
EL RIEGO												
Tc 50, XIV	3	60	4.0							19	380	6.3
Tc 50, XV										21	840	14.0
Tc 50, XVI	1	50	3.3							23	1,150	19.2

Zone / phase	Grass quids: no. of quids	quids x PF	estimated liters of food (60 quids per l.)	Opuntia and other cactus stems: no. of stem fragments	stems x PF	estimated liters of food (10 stems per l.)	Ceiba parvifolia root: no. of roots or fragments	roots x PF	estimated liters of food (60 roots per l.)	Wild Cucurbita spp: no. of seeds and or seeds	no. of whole specimens x PF	estimated liters (1 cucurbit per l.)
VENTA SALADA												
Tc 35e, A	29	29	0.5	2	2	0.2				2	1	1.0
Tc 50, I	20	20	0.3	10	10	1.0				2	1	1.0
Tc 50, II	58	58	1.0	78	78	7.8	4	4	0.1	5	1	1.0
Tc 35e, B	27	27	0.5	7	7	0.7				1	1	1.0
Tc 50, III	57	57	1.0	69	69	6.9	7	7	0.1	3	1	1.0
Tc 255, A				13	65	6.5						
Tc 35e, C	85	85	1.4	12	12	1.2						
PALO BLANCO												
Tc 35e, D	57	57	1.0	3	3	0.3				2	1	1.0
Tc 35e, E				12	36	3.6	4	12	0.2			
Tc 50, IV	93	93	1.6				2	2	*			
Tc 254, B	139	139	2.3	9	9	0.9						
Tc 254, C'	49	49	0.8				1	1	*			
Tc 50, V	39	117	2.0	20	60	6.0	6	18	0.3			
Tc 272, A	3	6	0.1									
Tc 272, B				3	12	1.2	47	188	3.1			
Tc 272, C	10	40	0.7	1	4	0.4						
Tc 272, D	81	405	6.8	10	50	5.0						
Tc 272, E	107	535	8.9	18	90	9.0						
Tc 50, VI				50	50	5.0	47	47	0.8			
Tc 272, F	28	140	2.3									
SANTA MARIA												
Tc 50, VII	68	136	2.3	26	52	5.2	315	630	10.5			
Tc 272, G	4	80	1.3									
Tc 272, H												
Tc 272, I	2	100	1.7									
AJALPAN												
Tc 254, C	18	72	1.2									
Tc 272, J	6	300	5.0	1	50	5.0						
ABEJAS												
Tc 50, VIII	14	70	1.2	4	20	2.0	12	60	1.0			
Tc 50, IX	14	70	1.2	15	75	7.5	39	195	3.3			
Tc 254, D	7	35	0.6	1	5	0.5						
Tc 50, X	1	30	0.5	29	870	87.0						
COXCATLAN												
Tc 50, XI	52	416	6.9	57	456	45.6	24	192	3.2			
Tc 254, E-F	1	12	0.2									
Tc 50, XII	5	60	1.0	8	96	9.6						
Tc 50, XIII	7	84	1.4	6	72	7.2	1	12	0.2			
EL RIEGO												
Tc 50, XIV	4	80	1.3	10	200	20.0				1	20	20.0
Tc 50, XV	3	120	2.0	1	40	1.0						
Tc 50, XVI	1	50	0.8									

Zone / phase	Zea mays wild type: no. of cobs	cobs x PF x 55 kernels per cob	estimated liters (10,000 kernels per l.)	Apodanthera sp.: no. of seeds	whole specimens x PF	estimated liters (1 cucurbit per l.)	Total of food liters from wild plants	Percent of diet
VENTA SALADA							120.3	8
Tc 35e, A				11	1	1.0	8.2	5
Tc 50, I							7.9	4
Tc 50, II							41.9	13
Tc 35e, B				125	1	1.0	7.8	6
Tc 50, III							30.2	7
Tc 255, A							7.9	15
Tc 35e, C							16.4	6
PALO BLANCO							330.9	17
Tc 35e, D				23	1	1.0	9.0	8
Tc 35e, E							5.8	9
Tc 50, IV							35.8	17
Tc 254, B	1	55	*				11.6	13
Tc 254, C'	5	275	*				4.7	31
Tc 50, V							55.1	15
Tc 272, A							4.0	9
Tc 272, B							7.2	18
Tc 272, C							3.9	4
Tc 272, D							29.6	27
Tc 272, E	4	1,100	0.1				77.6	24
Tc 50, VI							76.4	25
Tc 272, F							10.2	23
SANTA MARIA							103.1	17
Tc 50, VII	45	4,950	0.5				69.7	23
Tc 272, G							15.3	9
Tc 272, H							5.6	9
Tc 272, I							12.5	17
AJALPAN							16.6	18
Tc 254, C	30	6,600	0.7				5.5	18
Tc 272, J							11.1	19
ABEJAS							331.3	49
Tc 50, VIII	2	550	0.1				88.3	54
Tc 50, IX	7	1,925	0.2				75.4	41
Tc 254, D	43	11,825	1.2				17.7	68
Tc 50, X							149.9	49
COXCATLAN							500.7	52
Tc 50, XI	18	7,920	0.8				274.2	48
Tc 254, E-F	23	15,180	1.5				34.7	49
Tc 50, XII	5	3,300	0.3				118.8	60
Tc 50, XIII	9	5,910	0.6				73.0	52
EL RIEGO							372.6	45
Tc 50, XIV							115.3	38
Tc 50, XV							72.3	34
Tc 50, XVI							185.0	48

Note: Total volumes of food from all sources are listed, by phase and zone, in Table 36.
*Less than 0.05 liters.

Table 38. Volume of Food in Liters Estimated from Remains of Cultivated Plants by Zone and Phase

Zone and phase	Preservation factor PF	Capsicum annuum (chili pepper): no. of fragments	Capsicum: estimated whole specimens x PF	Capsicum: estimated liters of food (20 fruits per l.)	Amaranthus spp.: oz. of seed	Amaranthus: oz. of seed x PF	Amaranthus: estimated liters of food (33.8 oz. per l.)	Persea americana (avocado): no. of seeds	Persea: seeds x PF	Persea: estimated liters of food (30 fruits per l.)	Cucurbita mixta (squash): no. of peduncles and/or seeds	C. mixta: estimated whole specimens x PF	C. mixta: estimated liters of food (1 cucurbit per l.)
VENTA SALADA													
Tc 35e, A	0	8	8	0.26				6	6	0.2			
Tc 50, I	0							3	3	0.1	17	17	17.0
Tc 50, II	0	1	1	0.03	6	6	0.2	7	7	0.2	13	13	13.0
Tc 35e, B	0	2	2	0.06				8	8	0.3			
Tc 50, III	0				78	78	2.3	7	7	0.2	19	19	19.0
Tc 255, A	5										1	5	5.0
Tc 35e, C	0	2	2	0.06	8	8	0.2	8	8	0.3			
PALO BLANCO													
Tc 35e, D	0				2	2	0.06	8	8	0.3	2	2	2.0
Tc 35e, E	3							3	9	0.3	2	6	6.0
Tc 50, IV	0	1oz.	1	0.03	34	34	1.0	15	15	0.5	4	4	4.0
Tc 254, B	0				5	5	0.2						
Tc 254, C'	0												
Tc 50, V	3	1oz.	3	0.02	2	6	0.2	14	42	1.4			
Tc 272, A	2												
Tc 272, B	4												
Tc 272, C	4										1	4	4.0
Tc 272, D	5							6	30	1.0			
Tc 272, E	5										1	5	5.0
Tc 50, VI	0	7	7	0.23	44	544	16.0	85	85	2.8	3	3	3.0
Tc 272, F	5	1	5	0.16									
SANTA MARIA													
Tc 50, VII	2	5	10	0.33	1	2	0.1	35	70	2.3	7	14	14.0
Tc 272, G	20							5	100	3.3	1	20	20.0
Tc 272, H	30							1	30	1.0			
Tc 272, I	50												
AJALPAN													
Tc 254, C	4												
Tc 272, J	50												
ABEJAS													
Tc 50, VIII	5	4	20	0.66	1	5	0.2	4	20	0.6	4	5	5.0
Tc 50, IX	5	3	15	0.50	1	5	0.2	2	10	0.3			
Tc 254, D	5												
Tc 50, X	30				1	30	0.9						
COXCATLAN													
Tc 50, XI	8	3	24	0.80				32	256	8.5			
Tc 254, E-F	12												
Tc 50, XII	12	2	12	0.40	1	12	0.4	1	12	0.4			
Tc 50, XIII	12	1	12	0.40							1	12	12.0
EL RIEGO													
Tc 50, XIV	20	3	40	1.33	*	–	–	2	40	1.3	1?	20	20.0
Tc 50, XV	40	3	120	4.40	*	–	–	5	200	6.6			
Tc 50, XVI	50	1	50	1.66	*	–	–	3	150	5.0			

Zone and phase	Lagenaria siceraria (bottle gourd): no. of rind fragments	Lagenaria: estimated whole specimens x PF	Lagenaria: estimated liters of food (1 cucurbit per l.)	Zea mays (maize) early cultivated race: estimated no. of whole cobs	Zea early cultivated: whole cobs x PF x 120 kernels per cob	Zea early cultivated: estimated liters of food (8000 kernels per l.)	Cucurbita moschata (squash): no. of peduncles and/or seeds	C. moschata: estimated whole specimens x PF	C. moschata: estimated liters of food (1 cucurbit per l.)	Diospyros digyna (black sapote): no. of peduncles and/or seeds	Diospyros: estimated whole specimens x PF	Diospyros: estimated liters of food (5 fruits per l.)
VENTA SALADA												
Tc 35e, A	8	1	1.0				1	1	1.0	1	1	0.2
Tc 50, I	19	2	2.0				1	1	1.0	1	1	0.2
Tc 50, II	11	1	1.0				26	1	1.0	7	5	1.0
Tc 35e, B							1	1	1.0	3	1	0.2
Tc 50, III	15	2	2.0				1	1	1.0	3	3	0.6
Tc 255, A				3	1,800	0.2						
Tc 35e, C	9	1	1.0							1	1	0.2
PALO BLANCO												
Tc 35e, D	2	1	1.0				1	1	1.0	1	1	0.2
Tc 35e, E												
Tc 50, IV	1	1	1.0							11	4	0.8
Tc 254, B				2	240	*						
Tc 254, C'				51	6,120	0.8						
Tc 50, V	1	3	3.0							9	9	1.8
Tc 272, A												
Tc 272, B												
Tc 272, C												
Tc 272, D				2	1,200	0.2						
Tc 272, E				1	600	0.1						
Tc 50, VI	3	1	1.0							91	13	2.6
Tc 272, F												
SANTA MARIA												
Tc 50, VII	1	2	2.0	35	8,400	1.0				13	24	4.8
Tc 272, G												
Tc 272, H										1	30	6.0
Tc 272, I												
AJALPAN												
Tc 254, C				38	18,240	2.3						
Tc 272, J				1	6,000	0.8						
ABEJAS												
Tc 50, VIII	2	5	5.0	7	4,200	0.5	1	5	5.0	6	30	6.0
Tc 50, IX	2	5	5.0	13	7,800	1.0	1	5	5.0	50	160	32.0
Tc 254, D				32	19,200	2.4						
Tc 50, X	2	30	30.0	1	3,600	0.5				5	150	30.0
COXCATLAN												
Tc 50, XI	2	8	8.0	3	2,880	0.4				2	8	1.6
Tc 254, E-F												
Tc 50, XII							1?	12	12.0			
Tc 50, XIII	1	12	12.0	1	1,440	0.2						
EL RIEGO												
Tc 50, XIV												
Tc 50, XV												
Tc 50, XVI												

Zone and phase	Casimiroa edulis (white sapote): no. of seeds	Casimiroa: estimated whole specimens x PF	Casimiroa: estimated liters of food (8 fruits per l.)	Phaseolus vulgaris (common bean): no. of pods and/or seeds	P. vulgaris: no. of beans (20 per pod) x PF	P. vulgaris: estimated liters of food (5000 beans per l.)	Cyrtocarpa procera (chupandilla): no. of seeds	Cyrtocarpa: seeds x PF	Cyrtocarpa: estimated liters of food (60 fruits per l.)	Zea mays (maize) early tripsacoid: estimated no. of whole cobs	Zea early tripsacoid: whole cobs x PF x 160 kernels per cob	Zea early tripsacoid: estimated liters of food (4000 kernels per l.)
VENTA SALADA												
Tc 35e, A	19	8	1.0	41	60	0.01	31	31	0.5			
Tc 50, I	1	1	0.1				47	47	0.8	22	3,520	0.9
Tc 50, II	2	2	0.3				119	119	1.9	1	160	*
Tc 35e, B	17	8	1.0	196	200	0.04	17	17	0.3			
Tc 50, III	3	3	0.4	3	40	0.01	136	136	2.3	18	2,880	0.7
Tc 255, A	1	5	0.6									
Tc 35e, C	66	7	0.9	156	180	0.03	12	12	0.2	20	3,200	0.8
PALO BLANCO												
Tc 35e, D	53	20	2.5	109	109	0.02	1	1	*			
Tc 35e, E	2	3	0.4	2	120	0.02	12	36	0.6	3	1,440	0.4
Tc 50, IV	4	2	0.3	1	20	*	206	206	3.4	41	6,560	1.6
Tc 254, B	3	2	0.3				1	1	*	226	36,160	9.0
Tc 254, C'										53	8,480	2.1
Tc 50, V	7	15	1.9	2	60	0.01	167	501	8.4	1	480	0.1
Tc 272, A							124	248	4.2			
Tc 272, B							54	216	3.6			
Tc 272, C							61	244	4.1			
Tc 272, D	3	5	0.6				249	1,245	20.7			
Tc 272, E	4	15	1.9				923	4,615	76.9			
Tc 50, VI	13	5	0.6	1	20	*	292	292	5.0	1,562	249,920	62.5
Tc 272, F	3	5	0.6				48	240	4.0			
SANTA MARIA												
Tc 50, VII	7	8	1.0				979	1,958	32.6	282	90,240	22.6
Tc 272, G	4	20	2.5				26	520	8.7			
Tc 272, H	1	30	3.8				4	120	2.0			
Tc 272, I							3	150	2.5	7	56,000	14.0
AJALPAN												
Tc 254, C										86	55,040	13.8
Tc 272, J										10	80,000	20.0
ABEJAS												
Tc 50, VIII	9	40	5.0	1	100	0.02	28	140	2.3	6	4,800	1.2
Tc 50, IX	1	5	0.6				1	5	0.1			
Tc 254, D										*	–	–
Tc 50, X							1	30	0.5	1	4,800	1.2
COXCATLAN												
Tc 50, XI	4	8	1.0	1	160	0.03	600	4,800	80.0			
Tc 254, E-F												
Tc 50, XII												
Tc 50, XIII												
EL RIEGO												
Tc 50, XIV												
Tc 50, XV												
Tc 50, XVI												

Zone and phase	Zea mays (maize) quids: no. of quids	Quids: quids x PF	Quids: estimated liters of food (60 quids per l.)	Zea mays (maize) Nal-Tel-Chapalote complex: estimated no. of whole cobs	Nal-Tel: whole cobs x PF x 310 kernels per cob	Nal-Tel: estimated liters of food (2700 kernels per l.)	Canavalia spp. (jack beans): no. of pods	Phaseolus acutifolius (tepary bean): no. of beans	P. acutifolius: beans x PF	P. acutifolius: estimated liters of food (5000 beans per l.)	Cucurbita pepo (pumpkin): no. of seeds, peduncles and/or flowers	C. pepo: estimated whole specimens x PF	C. pepo: estimated liters of food (1 cucurbit per l.)
VENTA SALADA													
Tc 35e, A	1	1	*	143	44,330	16.4					5	5	5.0
Tc 50, I	11	11	0.2	636	197,160	73.0					3	3	3.0
Tc 50, II	22	22	0.4	601	186,310	69.0					1	1	1.0
Tc 35e, B				160	49,600	18.4					1	1	1.0
Tc 50, III	30	30	0.5	1,962	608,220	225.3					26	1	1.0
Tc 255, A	2	10	0.2	7	10,850	4.0							
Tc 35e, C	17	17	0.3	466	144,460	53.5					2	2	2.0
PALO BLANCO													
Tc 35e, D				140	43,400	16.1					1	1	1.0
Tc 35e, E	1	3	0.1	12	11,160	4.1					12	3	3.0
Tc 50, IV	1	1	*	597	185,070	68.5							
Tc 254, B	58	58	1.0	123	38,130	14.1					1	1	1.0
Tc 254, C'				10	3,100	1.1							
Tc 50, V	1	3	0.1	190	176,700	65.4							
Tc 272, A	8	16	0.3	89	55,180	20.5							
Tc 272, B	4	16	0.3	31	38,440	14.2							
Tc 272, C	1	4	0.1	80	99,200	36.8							
Tc 272, D	8	40	0.7	26	40,300	14.9							
Tc 272, E	4	20	0.3	95	147,250	54.5							
Tc 50, VI				161	49,910	18.5		485	455	0.09			
Tc 272, F				13	20,150	7.5					1	5	5.0
SANTA MARIA													
Tc 50, VII	1	2	*	54	33,480	12.4							
Tc 272, G	2	40	0.7	20	124,000	45.9							
Tc 272, H	13	390	6.5	4	37,200	13.8							
Tc 272, I	11	550	9.2	2	31,000	11.5							
AJALPAN													
Tc 254, C				8	9,920	3.7					1	4	4.0
Tc 272, J	6	300	5.0										
ABEJAS													
Tc 50, VIII	8	40	0.7				1	118	590	0.12			
Tc 50, IX				2	3,100	1.2							
Tc 254, D	9	45	0.8										
Tc 50, X													
COXCATLAN													
Tc 50, XI													
Tc 254, E-F	9?	108	1.8										
Tc 50, XII													
Tc 50, XIII													
EL RIEGO													
Tc 50, XIV													
Tc 50, XV													
Tc 50, XVI													

Zone and phase	Sideroxylon cf. tempisque (cosahuico): no. of seeds	Sideroxylon: estimated whole specimens x PF	Sideroxylon: estimated liters of food (60 fruits per l.)	Acrocomia mexicana (coyol): no. of seeds	Acrocomia: seeds x PF	Acrocomia: estimated liters of food (60 fruits per l.)	Spondias mombin (ciruela): no. of seeds	Spondias: seeds x PF	Spondias: estimated liters of food (60 fruits per l.)	Crescentia cujete (tree gourd): no. of rinds	Crescentia: estimated whole specimens x PF	Crescentia: estimated liters of food (1 cucurbit per l.)
VENTA SALADA												
Tc 35e, A	1	1	*				2	2	*	6	1	1.0
Tc 50, I	9	9	0.2	4	4	0.1	4	4	0.1	3	1	1.0
Tc 50, II	43	43	0.7	4	4	0.1	63	63	1.1	1	1	1.0
Tc 35e, B	2	2	*	1	1	*						
Tc 50, III	58	58	0.9	5	5	0.1	25	25	0.4	3	1	1.0
Tc 255, A												
Tc 35e, C	8	8	0.1	2	2	*	2	2	*	3	1	1.0
PALO BLANCO												
Tc 35e, D				1	1	*				2	1	1.0
Tc 35e, E	15	45	0.8				13	39	0.7			
Tc 50, IV	438	438	7.2									
Tc 254, B	1	1	*							5	1	1.0
Tc 254, C'												
Tc 50, V	74	222	3.7	23	69	1.2	4	12	0.2			
Tc 272, A	4	8	0.1	1	2	*	8	16	0.3			
Tc 272, B	1	4	0.1				7	28	0.5			
Tc 272, C				18	72	1.2	24	96	1.6	5	4	4.0
Tc 272, D	33	165	2.8	68	340	5.7	254	1,270	22.2			
Tc 272, E	30	150	2.5	68	340	5.7	512	2,560	42.7			
Tc 50, VI	177	177	2.9	46	46	0.8	19	19	0.3			
Tc 272, F	92	460	7.7	37	185	3.1	17	85	1.4			
SANTA MARIA												
Tc 50, VII	166	332	5.5	6	12	0.2	57	114	1.9	1	2	2.0
Tc 272, G	194	3,880	64.7	7	140	2.3	2	40	0.7			
Tc 272, H	1	30	0.5									
Tc 272, I												
AJALPAN												
Tc 254, C												
Tc 272, J												
ABEJAS												
Tc 50, VIII												
Tc 50, IX												
Tc 254, D												
Tc 50, X												
COXCATLAN												
Tc 50, XI												
Tc 254, E-F												
Tc 50, XII												
Tc 50, XIII												
EL RIEGO												
Tc 50, XIV												
Tc 50, XV												
Tc 50, XVI												

Zone and phase	Zea mays (maize) late tripsacoid: estimated no. of whole cobs	Late tripsacoid: whole cobs x PF x 400 kernels per cob	Late tripsacoid: estimated liters of food (2000 kernels per l.)	Zea mays (maize) Zapalote Chico race: estimated no. of whole cobs	Zapalote Chico: whole cobs x PF x 300 kernels per cob	Zapalote Chico: estimated liters of food (2000 kernels per l.)	Zea mays (maize) Slender Pop race: estimated no. of whole cobs	Slender Pop: cobs x PF x 300 kernels per cob	Slender Pop: estimated liters of food (2300 kernels per l.)	Phaseolus coccineus (runner bean): no. of pods and/or seeds	P. coccineus: estimated beans (20 per pod) x PF	P. coccineus: estimated liters of food (5000 beans per l.)
VENTA SALADA												
Tc 35e, A	233	93,200	46.6	23	6,900	3.5	209	62,700	27.2	24	40	0.02
Tc 50, I	215	86,000	43.0				123	36,900	16.0			
Tc 50, II	353	141,200	70.6				482	144,600	62.9			
Tc 35e, B	105	42,000	21.0	4	1,200	0.6	264	79,200	34.4			
Tc 50, III	416	166,400	83.2				117	35,100	15.3	1	20	0.01
Tc 255, A							33	49,500	21.5			
Tc 35e, C	479	191,600	95.8				418	125,400	54.5	6	20	0.01
PALO BLANCO												
Tc 35e, D	100	40,000	20.0				1	300	0.1			
Tc 35e, E	26	31,200	15.6				1	900	0.4			
Tc 50, IV	559	223,600	111.8	2	600	0.3	104	31,200	13.6			
Tc 254, B	93	37,200	18.6	2	600	0.3						
Tc 254, C'	15	6,000	3.0									
Tc 50, V	289	346,800	173.4				2	1,800	0.8			
Tc 272, A	12	9,600	4.8				35	21,000	9.1			
Tc 272, B							27	32,400	14.1			
Tc 272, C	12	19,200	9.6				13	15,600	6.8			
Tc 272, D	7	14,000	7.0				5	7,500	3.3			
Tc 272, E	14	28,000	14.0				26	39,000	17.0			
Tc 50, VI	291	116,400	58.2	1	300	0.2				21	20	0.01
Tc 272, F												
SANTA MARIA												
Tc 50, VII	73	58,400	29.2	1	600	0.3	2	1,200	0.5	1	40	0.02
Tc 272, G												
Tc 272, H												
Tc 272, I												
AJALPAN												
Tc 254, C												
Tc 272, J												
ABEJAS												
Tc 50, VIII												
Tc 50, IX												
Tc 254, D												
Tc 50, X												
COXCATLAN												
Tc 50, XI												
Tc 254, E-F												
Tc 50, XII												
Tc 50, XIII												
EL RIEGO												
Tc 50, XIV												
Tc 50, XV												
Tc 50, XVI												

Zone and phase	Physalis spp. (ground cherry): no. of fruits	Physalis: estimated liters of food (30 fruits per l.)	Zea mays (maize) Zapalote Grande race: estimated no. of whole cobs	Zapalote Grande: whole cobs x PF x 300 kernels per cob	Zapalote Grande: estimated liters of food (2300 kernels per l.)	Arachis hypogaea (peanut): no. of specimens	Arachis: estimated liters of food (400 nuts per l.)	Psidium guajava (guava): no. of fruits	Psidium: estimated liters of food (30 fruits per l.)	Phaseolus lunatus (sieva bean): no. of pods and/or seeds	P. lunatus: estimated beans (20 per pod) x PF	P. lunatus: estimated liters of food (5000 beans per l.)	Zea mays (maize) combined late races: estimated no. of whole cobs	Combined late races: cobs x PF x 3000 kernels per cob	Combined late races: estimated liters of food (2300 kernels per l.)	Total liters from cultivated plants	Percent of diet
VENTA SALADA																1,192.8	75
Tc 35e, A										2	20	0.01	3	900	0.4	104.3	68
Tc 50, I						2	0.01						1	300	0.1	158.8	83
Tc 50, II						2	0.01									225.4	71
Tc 35e, B			1	300	0.1								1	300	0.1	78.5	55
Tc 50, III										1	20	0.01	208	62,400	27.1	383.4	87
Tc 255, A																31.5	63
Tc 35e, C										1	20	0.01				210.9	72
PALO BLANCO																1,247.9	65
Tc 35e, D																45.3	39
Tc 35e, E																32.4	51
Tc 50, IV																214.0	72
Tc 254, B	25	0.8														46.3	50
Tc 254, C'	28	0.9														7.9	52
Tc 50, V																261.6	72
Tc 272, A																39.3	89
Tc 272, B																32.8	80
Tc 272, C																64.2	71
Tc 272, D																79.1	72
Tc 272, E																220.6	68
Tc 50, VI			1	300	0.1	1	*	4	0.1							174.9	56
Tc 272, F																29.5	67
SANTA MARIA																352.4	58
Tc 50, VII																132.8	45
Tc 272, G																148.8	88
Tc 272, H																33.6	48
Tc 272, I																37.2	52
AJALPAN																49.6	55
Tc 254, C																23.8	79
Tc 272, J																25.8	43
ABEJAS																144.5	21
Tc 50, VIII																32.3	20
Tc 50, IX																45.9	25
Tc 254, D																3.2	12
Tc 50, X																63.1	21
COXCATLAN																139.9	14
Tc 50, XI																100.3	18
Tc 254, E-F																1.8	3
Tc 50, XII																13.2	7
Tc 50, XIII																24.6	18
EL RIEGO																40.3	5
Tc 50, XIV																22.6	7
Tc 50, XV																11.0	5
Tc 50, XVI																6.7	2

Note: Total volumes of food from all sources are listed, by phase and zone, in Table 36.
*Less than 0.05 liter.

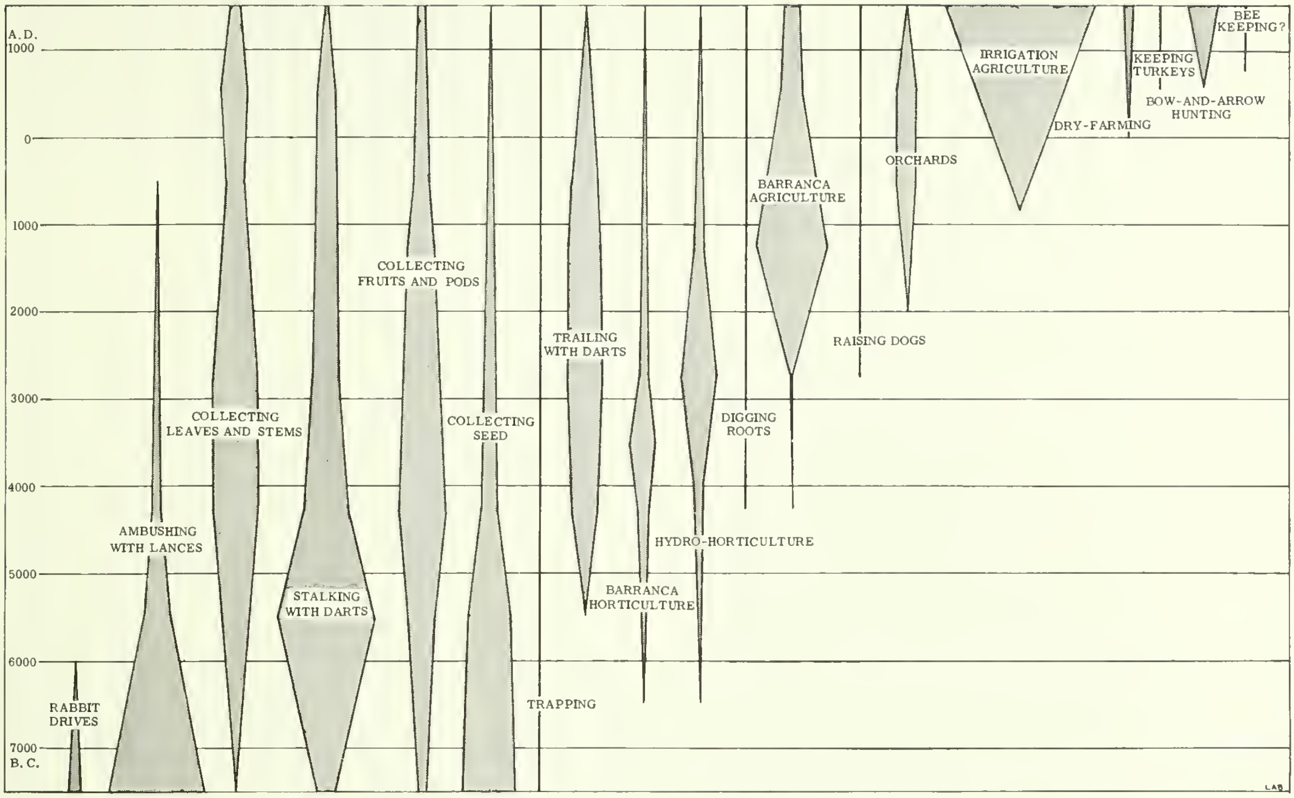

Fig. 188. The relative importance of various subsistence activities.

its meat from hunted animals. Two percent lance points suggest that nearly one percent of the meat came from ambush hunting, 38 percent heavy dart points suggests that 10 percent came from stalking, and 60 percent thin dart points suggests that 16 percent came from bleeding and trailing.

In the Ajalpan phase about 22 percent of the meat came from big game. The projectile points were 5 percent lance points (one pereent ambush hunting), 37 percent heavy dart points (8 percent stalking), and 58 percent thin dart points (13 percent bleeding and trailing). The Santa Maria phase, with 20 percent of the meat from hunting, had 5 percent lance points, 49 percent heavy dart points, and 46 percent thin dart points —or one percent of the meat from ambush hunting, 10 percent from stalking, and 9 percent from bleeding and trailing. In the Palo Blanco phase hunting accounted for 13 percent of the meat. Seventy percent of the points were large and barbed; 20 percent were thin, slashing dart points; and 10 percent were arrowpoints. That is, 9 percent of the meat came from stalking, 3 percent from bleeding and trailing, and one percent from bow-and-arrow hunting. In the Venta Salada horizon, only 12 percent of the meat was derived from large game. The projectile points were 58 percent arrow points, accounting for 7 percent of the meat; 11 percent thin dart points (one percent of the meat), and 31 percent heavy dart points (4 percent of the meat).

In the earliest phase of the Tehuacan sequence, the Ajuereado culture, which in terms of trends probably derived about 60 percent of its subsistence from hunting, the lance points outnumber the barbed dart points by two to one (42 percent of the big game from ambushing and 18 percent from dart stalking). The large quantities of rabbit bones in Zones XXV and XXVI seem to Flannery (Chapter 8) to be the probable result of rabbit drives. Perhaps 6 percent of the food came from this activity and about 4 percent from trapping and collecting.

A perusal of the wild plants we uncovered reveals at least four kinds of plant gathering that have slightly different periods of popularity. They are collecting seeds, picking fruits and pods, cutting leaves or stems, and digging roots. The tools for these activities were an instrument with a sharp edge for cutting and a container for the stuffs collected—perhaps a basket for

seeds; a net bag for fruits, leaves, and roots; and a carrying loop for leaves. In the El Riego phase the major part of the plant food came from collected wild seeds. Fruits represented only half the quantity of seeds, and cactus stems and agave leaves were even less popular. In the Coxcatlan phase, the wild seeds decreased in popularity while fruits, leaves, and stems increased and a few roots occur for the first time. These trends continue without much modification in the Abejas phase. However, with an increasing portion of the food coming from cultivated plants, subsistence activities based on collecting wild plants begin to diminish and diminish gradually throughout the remainder of the sequence. These subsistence trends are shown graphically in Fig. 188.

Some of the activities connected with plant domestication are relatively short lived and rise and fall within our sequence, but others steadily increase. The earliest agriculture seems to have been practiced in the El Riego phase and even it seems to be of two kinds. One kind, represented by cultivated squash, is what I have called "barranca horticulture." By this term I mean the planting of individual hardy cultivars in the barrancas near the cave sites. Whether the plants grew in actual gardens or not is open to question. The other kind of early planting has been called "hydro-horticulture," and means that individual domesticates—avocado trees and chili plants—were planted beside springs or along the flanks of the Rio Salado where they received a steady year-round supply of water. These two types of cultivation each accounted for about 2.5 percent of the total diet.

In the Coxcatlan phase increased amounts of food were derived from both barranca horticulture (5 percent) and hydro-horticulture (4 percent). There is also the first evidence (less than one percent) of corn planted in barranca agriculture. By "barranca agriculture" I mean the planting of such grains as corn and amaranth in fields (albeit in this phase very small), in the arroyo bottoms, or on low terraces next to arroyos or barrancas where they would receive a supply of moisture from runoff during the rainy season. In the Abejas phase increased amounts of cultivars were produced from these three activities: barranca horticulture, 9 percent; hydro-horticulture, 14 percent; and barranca agriculture, 1 percent (representing a few improved corn races).

A radical shift in this pattern occurs in the Ajalpan phase, for produce from both barranca horticulture (3 percent) and hydro-horticulture (2 percent) decreases, while the proportion of improved corn derived from barranca or flood-plain agriculture rises to 35 percent of the bulk food stuffs. The complexity of the first dam built near Purron Cave early in the following phase suggests that perhaps in the Ajalpan phase some irrigation and orchard agriculture was undertaken. The appearance of certain fruits needing supplementary water as early as the Coxcatlan phase lends support to this theory.

From Santa Maria times on it becomes difficult to tell what produce came from dry farming and what came from wet farming. I tend to think of the squashes from Coxcatlan Cave as being products of barranca horticulture (3 percent), the fruits as products of hydro-horticulture (3 percent) and the corn as being from barranca agriculture (23 percent). However, I regard corn from floors of Purron Cave that are contemporaneous with the dam as being from irrigation agriculture (9 percent) and the fruits from orchard agriculture (7 percent). Obviously this is a somewhat arbitrary division, and attempting to separate products of the two kinds of activities in the last two phases is even more arbitrary. Certainly in both the Palo Blanco and Venta Salada phases products of barranca horticulture and hydro-horticulture account for no more than one percent of the total food—perhaps becoming, as they are today in the Tehuacan Valley, the fruit of the odd avocado or sapote tree in the well-watered patio or of a few squash or chili plants growing near the chicken coop, or in the Palo Blanco and Venta Salada periods, the turkey coop. Most of the fruits must have come from well-watered orchards, which perhaps produced about 7 percent of the diet in the Palo Blanco period and only one percent in the final period. Increasing amounts of corn and increasing numbers of irrigation features in both phases make me suspect that irrigation agriculture was the major subsistence activity, at least as far as food production is concerned. However, some sites and caves were located along barrancas, so barranca agriculture must have persisted, as it still does today. In Fig. 188 I have arbitrarily shown it to represent 10 percent of the food produced in Palo Blanco and Venta Salada times.

Today slash-and-burn agriculture is practiced sparingly along mountain flanks of the valley. When this method began prehistorically is difficult to tell. The only hints we have come from the site survey, which shows a few hillside sites attributable to the Venta Salada phase and even fewer dating back to Palo Blanco times. I would guess that slash-and-burn farming contributed no more than 3 percent of the valley's diet in the Venta Salada phase and even less (one percent) in the Palo Blanco phase. This would mean that about 40 percent of the food produced in the Palo

Blanco period and 60 percent in the Venta Salada period were derived from irrigation. The increased numbers of irrigation features attributed to the final phase are consistent with these estimates.

In summary, our study of subsistence activities shows a steady increase in food production owing to more efficient means of production. In other words, people got more and more food by expending decreasing amounts of energy. Not only that, but the food produced yielded larger quantities of protein per unit of measure, or more and more food energy. In terms of our present analytical techniques we have not been able to quantify the energy going into subsistence activity or the energy derived from the food utilized, but there is little doubt that as time spent in food-getting activities decreased, the food energy increased. Throughout our sequence more time and more energy became available for other activities.

For the most part other archaeological sequences from Mesoamerica are not so complete as the one from Tehuacan, nor do they have sufficient recovered food stuffs to reconstruct the changes in the subsistence. Nevertheless, when one looks at them from a not too critical standpoint some general trends are evident. Certainly there was a trend toward increased and improved food by more effective means of production.

This does not mean, however, that all cultures evolving in the varied ecological zones of the Mesoamerican culture area went through the same specific subsistence developments or even the same stages of economic evolution revealed in the Tehuacan Valley. In other words, the specific aspects of the sustenance, food preparation, and subsistence activities that changed through time in the unique ecological zone that includes the Tehuacan Valley cannot be considered typical of all Mesoamerica, nor can one generalize that all other ecological zones of Mesoamerica underwent the same kind of evolution in subsistence pattern as did the Tehuacan Valley.

A brief comparison of the Tehuacan subsistence sequence with rather tentative reconstructions of subsistence patterns from other regions in terms of general time periods brings out this point rather clearly. Unfortunately, information on the subsistence of the earliest period, from before 7000 B.C., is too sparse to be enlightening, so we shall begin with the period from 7000 to 5000 B.C.

A comparison of the two Mesoamerican archaeological complexes of this period with the most subsistence information—El Riego of Tehuacan, a highland desert valley, and Infiernillo of the Ocampo region of southwest Tamaulipas, a dry mesquite desert in deep canyons—does reveal some similarities. Both cultures relied chiefly on a meat diet, with most of the meat obtained from hunting and a small proportion from trapping or collecting, but even here there is a measure of difference. The El Riego diet consisted of over 50 percent meat, and the Infiernillo diet of only 40 percent meat. The greater amounts of wild plant finds in Infiernillo—about 59 percent as against 45 percent for El Riego—also may be significant. The El Riego complex seemed to derive about 5 percent of its food from agricultural produce, whereas Infiernillo similarly derived about one percent. Even here the domesticated plants were different, there being a few seeds of pumpkins and gourds in Infiernillo, whereas El Riego had avocado, cultivated squash, and probably chili and amaranth.

When one compares the El Riego and Infiernillo materials with the reconstruction of the subsistence pattern based only on bones and artifacts from Santa Marta Cave, located in a basin surrounded by tropical rain forest in Chiapas, further differences become apparent. The Santa Marta people derived as much as 70 percent of their diet from wild plants and only about 30 percent from animals, and they left no evidence of agriculture. The similarity of the Santa Marta crude artifacts to those José Luis Lorenzo uncovered in the lower levels of shell middens at Islona de Chantuto, in swampy lowlands on the Pacific coast of Chiapas, suggests that the two complexes were perhaps contemporaneous and that on the Chiapas coast there was still another type of subsistence—shell-food collecting.

These hints of different types of subsistence in different ecological zones of our poorly documented first period become clearer as evidence for the reconstruction of subsistence patterns increases for the next period, 5000 to 2300 B.C. In Tehuacan use of wild plants decreases from the Coxcatlan to the Abejas phase (from 52 to 49 percent), as does use of meat (34 to 30 percent), contrasting with an increase in agricultural produce in the two phases from 14 to 21 percent. Flannery's recent excavations of similar archaeological phases in caves near Mitla, Oaxaca, in a somewhat more mesic highland environment, seems to reveal a similar subsistence pattern, but perhaps with a slightly smaller proportion of the diet from meat and more from plant collecting.

Both sequences representative of this period in Tamaulipas, one in the Sierra de Tamaulipas and the other in Infiernillo Canyon, show similar decreases in meat and wild plant remains with concomitant increases in agricultural produce. Again, however, amounts of wild plant remains are greater than those in

Tehuacan and agricultural remains do not become so abundant. It should be noted that whereas by the end of this period most of the agricultural produce of all these sequences is composed of corn, beans, squash, chili, and amaranth, these plants were domesticated in different regions and arrived in the respective sequences at different times.

Nevertheless, there are some similarities in the kinds of plant remains for these varied areas which contrast with inadequate estimates that can be made for coastal cultural phases of 5000 to 2300 B.C. The pre-ceramic levels found by Charles Brush at Puerto Marquez, Guerrero, had many shellfish and fish and animal bones, and no mortars, manos, or metates. The late preceramic phase of Islona de Chantuto in coastal Chiapas and the huge preceramic sites in the fossil sand dunes near Viejon in central Veracruz seem to have about the same kinds of materials. The bones and shells suggest that the people of these cultures were predominately hunters, fishermen, and gatherers of shell-food, and perhaps did some plant collecting. The lack of manos and metates indicates that they did not grind corn and hints that they did not practice corn agriculture.

This suggestion that some of the lowland cultures of the period before 2300 B.C. did not have corn agriculture is bolstered by the absence of corn in the pollen profile of Santa Marta Cave, with a slightly different environment. It must be added, however, that the late Santa Marta remains reveal a still different subsistence pattern, one of plant collecting and animal hunting and collecting. Thus again the period from 5000 to 2300 B.C. shows varying subsistence patterns in different ecological zones.

In the next period, from 2300 to 200 B.C., we have large amounts of archaeological remains from many ecological zones of Mesoamerica. Unfortunately, preserved food stuffs are absent from most of these archaeological complexes, so subsistence estimates are for the most part very speculative. Nevertheless, it seems safe to assume that agriculture based on corn, beans, squash, chili peppers, and amaranth was practiced throughout Mesoamerica, although some of these plants were grown in different proportions in different ecological zones. Other domesticated plants may have varied from one area to another.

The biggest difference, however, seems to have been in the means of production of the agriculture. In Tehuacan some of the agricultural food resulted from dry farming and the planting of garden plots and terraced fields in the barrancas, but increasing amounts of food through the period came from irrigation agriculture and from fruit trees planted in watered orchards. Recent studies of materials from dry caves in the Mitla area indicate that a similar situation prevailed in that region, although the growing of beans seems to have been far more important than it was in Tehuacan (Flannery, personal communication). Vague hints from the Valley of Mexico, with still another environment, suggest similar means of production to those in the Puebla and Oaxaca areas. In Tamaulipas, where the mesquite desert environment is very different from southern Puebla and Oaxaca, agricultural food seems to have been produced almost entirely by dry farming, along with some barranca agriculture and gardening. The subsistence pattern from the Veracruz tropical lowlands is difficult to reconstruct, but there are hints that dry farming, flood-plain agriculture, and perhaps fruit growing were supplementing plant collection and the rich harvest from the sea. The Pacific coastal area of Guatemala, with a similar environment, may have had a similar subsistence pattern. People of the central Chiapas basin may have evolved a similar agricultural pattern, but deriving less from food collection than did the coastal regions. The Maya lowland cultures of this period are usually thought of as having an agriculture based on slash-and-burn farming, and there are hints that highland Guatemala (and perhaps the mountain-ridge areas of central Mexico) may have used slash-and-burn techniques in a different way. Thus it seems possible that the varieties of food production used in the previous period became greater from 2300 to 200 B.C.

By the final period, from 200 B.C. to the Spanish conquest, not only had the corn-squash-bean-chili-amaranth complex spread throughout Mesoamerica, but so had many other Mesoamerican domesticates and even a few of South American origin. In Tehuacan, the majority of the food was produced by irrigation, but within the valley, often in micro-environments, a variety of other agricultural techniques were employed. In the Mitla area irrigation was also used, but because of a slightly different and wetter environment other techniques, such as dry-farming and flood-plain farming, were of considerable importance. Although the subsistence data are very inadequate, a similar situation may have existed in the Valley of Mexico, but here the *chinampa* type of agriculture played an important part.

In Morelos, there was more emphasis on irrigation agriculture, particularly in the area near Xochicalco, but there may have been considerable variation in agricultural practices in terms of adaptation to micro-environments in this region also. In better-watered

areas, such as mountain tops or flanks throughout the *altiplano*, irrigation may have been relied on less and other agricultural techniques more than in the broader and drier valleys. Nevertheless, in the entire altiplano, irrigation seems to have been used to some extent, in contrast to the lowland regions, where irrigation was rarely employed. In central Veracruz, near Cempoala, rainfall was supplemented by the use of irrigation. In Postclassic highland Guatemala one finds terraced hillsides. In Maya lowlands and coastal regions slash-and-burn or flood-plain agriculture seem for the most part to have been used, but I would suspect that a careful study might reveal considerable variation of agricultural practices according to environmental differences within the lowland zone. In the dry northland of Tamaulipas, dry-farming seems to have continued in use; near the end of this period, perhaps due to "drought" conditions, it was not very successful. Dry northwest Mexico may have met this changing environmental situation by a gradual shift from dry-farming to increased reliance on irrigation agriculture.

From our superficial survey of Mesoamerican archaeological sequences the impression emerges of more effective food production of an increasing variety of plants, accomplished by a wide variety of agricultural practices that may represent local adaptive response to different ecological zones. It appears that all zones of Mesoamerica did not undergo exactly the same subsistence development as Tehuacan. In fact, it seems almost impossible to classify the subsistence data of all of Mesoamerica into one set of neat unilinear stages. One can, of course, classify the data into two very broad stages such as food-gathering and food-production, but finer divisions for all of Mesoamerica on the basis of the present meager subsistence information just cannot be done.

One gets the impression that the development of civilization and more effective food production in Mesoamerica is not due to a single evolution of developmental stages of culture and subsistence, but that a series of concomitant developments of rather different ecological zones are interacting with and interstimulating one another in such a manner as to bring about cultural development and increasingly effective food production. In fact, is not this sort of symbiotic development of agriculture and culture one of the causative processes that leads to effective food production and civilization in Mesoamerica? Or to put it another way, was not the development of effective food production and the concomitant cultural development in Mesoamerica in no small part owing to the fact that there were contiguous environments or ecological zones that were exploited agriculturally in different ways, and evolved through different cultural stages, and their geographical closeness allowed the varied subsistence developments to interact and interstimulate one another? Further, is not this symbiotic process which developed effective food production, and civilization, in Mesoamerica the same sort of process that must have occurred in other areas of primary civilizations, such as the Near East, Peru, or even China? If so, can we make universal or unilinear generalizations about civilization, other than the broad kind of statement that food-gathering preceded food-production, or that cultures developed from simple to complex? In fact, must not our generalizations about the development of agriculture and the rise of civilization be of the variety that Stewart has called "multilinear evolutions"? Is it not time, even with our meager data, to think in these terms? We hope that this volume with its ecological data and estimates of the changing subsistence pattern over nearly ten thousand years in the Tehuacan Valley is a step in this direction.

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AIB	*Anales del Instituto de Biología,* Universidad Nacional Autonoma, Mexico.
Am. Ant.	*American Antiquity,* Menasha and Salt Lake City.
AMNH-AP	American Museum of Natural History, Anthropological Papers, New York.
APS-P	American Philosophical Society, Proceedings, Philadelphia.
APS-T	American Philosophical Society, Transactions, Philadelphia.
BAE-B	Bureau of American Ethnology, Bulletin, Washington, D. C.
BML	*Botanical Museum Leaflets,* Harvard University, Cambridge, Mass.
CASY	*California Avocado Society Yearbook.*
IA	Ibero-Americana, University of California Press, Berkeley and Los Angeles.
INAH	Instituto Nacional de Antropologia e Historia, Mexico.
HMAI	*Handbook of Middle American Indians,* ed. by Robert Wauchope, University of Texas Press, Austin.
MBG-A	Annals of the Missouri Botanical Garden, St. Louis.
Mex. Ant.	*El Mexico Antiguo,* Sociedad Alemana Mexicanista, Mexico.
VFPA	Viking Fund Publications in Anthropology, New York.

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NOTE: Pages on which definitions or descriptions occur, or on which major material is concentrated, are indicated by bold type.

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by the inhabitants of the valley. Dr. Mangelsdorf contributes an analysis of the archaeological corn discovered by the Project. Hugh C. Cutler, Thomas W. Whitaker, Lawrence Kaplan, Stanley G. Stephens, and C. Earle Smith, Jr., discuss squashes and pumpkins, beans, cotton, and other plants brought under cultivation or used by man. An inventory of resident species of wild animals by Kent V. Flannery and a discussion of seasons when they were hunted, cast light on habits of the people.

The ancient inhabitants, represented by distressingly few skeletons, are discussed by Dr. James E. Anderson. New light on their food habits is shed by Eric O. Callen. Geological studies by Jean Brunet suggest reasons for the progressive dessication of the valley. A comparison of *Codex Borgia* with archaeological discoveries points to the possibility that this most colorful of aboriginal Mexican books came from the vicinity of the Tehuacan Valley.

Future volumes will cover other aspects of the Project: Volume II, non-ceramic artifacts; Volume III, a study of pottery from simplest beginnings to sophisticated vessels of the sixteenth century; Volume IV, a chronology of the Tehuacan Valley; Volume V, a description of the excavations and problems encountered, as well as ancient irrigation works; Volume VI, a summary of the Project.

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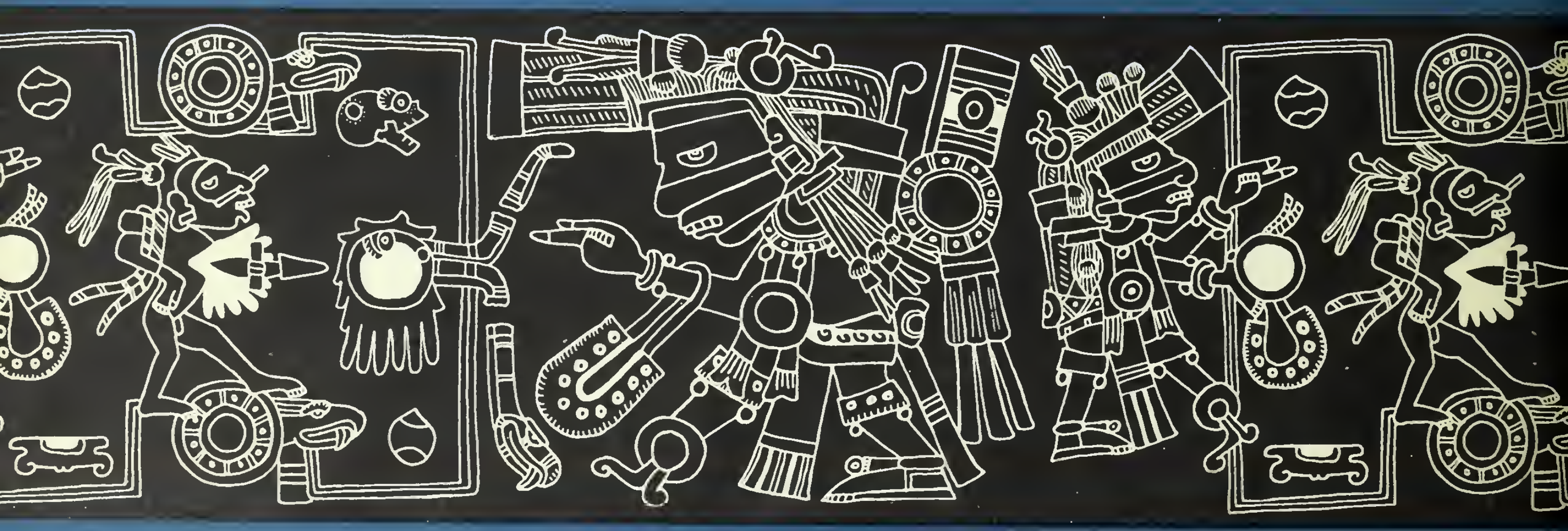

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